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THE

MINERAL SURVEYOR & VALUER'S COMPLETE GUIDE

COMPRISING A TREATISE ON IMPROVED MINING SURVEYING AND THE VALUATION OF MINING PROPERTIES

WITH

NEW TRAVERSE TABLES

By WILLIAM LINTERN

MINING AND CIVIL ENGINEER

FOURTH EDITION, WITH AN APPENDIX ON

MAGNETIC AND ANGULAR SURVEYING

WITH RECORDS OF THE PECULIARITIES OF NEEDLE DISTURBANCES

With Four Plates of Diagrams, Plans, &c.

LONDON

CROSBY LOCKWOOD AND SON

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1898.

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PREFACE.

THE TRAVERSE TABLES herewith submitted to the public were computed some years ago by the author, to supply a need he had often felt in his professional duties, when engaged in laying out works for the connection of different and distant operations in collieries and mines: viz. a Set of Tables by the use of which the results of some extensive surveys may be computed, and acted upon, with greater accuracy and confidence than can be sometimes attained by the ordinary methods of plotting.

It occurred to the author that if a survey were made with great care and accuracy, the results should be capable of computation with absolute certainty; and that thus much cost in mining operations would occasionally be saved, by the drivages meeting properly, as intended: for where the cost of driving is large, in hard ground for instance, frequently costing £3, or £4, or more per yard, an error even of 5 yards may thus become an expensive matter; and frequently also there will be no inconsiderable expense in endeavouring to "straighten" a crooked driving, which has resulted from incorrect "points" having been given.

It is not claimed for these Tables that they will supersede good surveying; on the contrary, if the sur-

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veying has been incorrectly done the Tables will not, and cannot, correct the error; but where the work of surveying has been done correctly, the employment of these Tables will eliminate the result much more unerringly than plotting; and thus they have often been proved by the author to be very useful and valuable.

Their application to surveys of mineral workings or openings which "pitch" highly must also be a matter of great utility, and they will supply a very ready medium, by which to ascertain the horizontal measure of the different pitches of the lines taken, which often vary very much in the same mine or colliery.

The use of the Magnetic needle is herein strongly defended, as being more generally applicable, as a rule, to mining surveying than any other system that can be suggested. But the author takes the liberty of submitting that the *magnetic meridian* is not a satisfactory "base" of working: and a description will be found herein of an improved circumferentor, by the use of which the True Meridian may be made the regular working "base," instead of the Magnetic Meridian; and by which the error occasioned by the constantly varying declination of the latter may be effectually guarded against.

A description is also given herewith of an improved protractor, by which the angles may be taken off directly from the instrument itself, instead of from points made in the paper either by the "folding arms" or pencil employed with the plainer kinds: this the author thinks must facilitate the making of a good and correct plan, and save the paper from those numerous punctures which are made in using the existing kinds of protractors.

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A general description of the operations of careful mining surveying will also be found in the chapters preceding the Tables; and some of the peculiarities, both of home and foreign mining, are there pointed out for the benefit of those who may have to engage therein, and prepare plans, etc. of the same.

A chapter is also given on the Valuation of mining properties, and some examples of the varying class of property connected with mining, which may be also occasionally useful.

The work of surveying etc. enters largely into mining, and the cost of mining is sometimes affected in no slight degree by the manner in which the work of the surveyor is accomplished: and he should therefore omit no opportunity of performing his task in a manner to yield the best possible results. If the accompanying matter and Tables will in any manner facilitate the attainment of these desiderata the author will be pleased, and his anticipations realized.

Possibly some errors may hereafter be discovered in the work, but as every care has been taken to ensure accuracy, it is hoped they will not be found to be numerous.

If any justification is considered necessary for having written this treatise with the Tables for publication, it is submitted in these few words:—the author does not doubt but that others have felt the want that he himself felt, before he set about the computation of these Tables; and that there are probably many who would like to avail themselves of such assistance as they may afford, at a less cost than that of having to construct them for themselves. Of the text it may be said that it seems to be but a natural accompaniment of the Tables.

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PREFACE TO THE SECOND EDITION.

THE subject of Magnetic Surveying having been a matter of inquiry with some persons who had purchased the first edition of this work; and there being a disposition with some people to depreciate the value of the magnetic needle as an instrument for surveying, accounting it of inferior practical value for the purposes indicated; I have been induced to add to this edition the leading results of a not inconsiderable experience in this field of labour, and the conclusions arrived at from a (perhaps) more than general close observation of the behaviour of the magnetic needle, under considerably varying circumstances.

That the magnetic needle is a very valuable instrument for certain operations in mining surveying there can, I think, be no doubt; and my object has been to show the class of operations in which it may be employed with advantage, as well as to indicate those which are more suited to a different method of surveying. It is hoped that the description and examples given will assist the thoughtful student to form an intelligent judgment in the matter treated of, and enable him to come to a right conclusion as to which system of working will be the most suitable to any particular class of work he may have in hand.

A few notes on colliery operations, &c., are added at the end, which it is hoped may be read with interest.

July, 1887.

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CHAPTER I.

PAPER FOR MAPS.

When a Survey of a property is about to be made for the purpose of obtaining a correct plan, it is important to secure a sheet of good paper mounted on cloth, of about the necessary size, and to keep it in a dry and moderately cool place for some few days before anything is done towards laying down any part of the survey; if this were not attended to, but the paper ordered from the maker and the plotting proceeded with immediately on its arrival, it would soon be discovered that lines which were laid down with care at the first according to scale, shew a different length on the scale being applied to them some little time after, supposing the paper to have remained in a dry room; and it would be a hopeless task to endeavour to get lines laid down subsequently, to "come in" correctly with those laid down at the first. Paper arriving fresh from the mill is sure to be more or less damp, and after it has been exposed a little time to a dry atmosphere the damp evaporates, and, as a natural consequence, the paper shrinks; and until ample time has been allowed for this evaporation, in a medium dry and warm room, the paper should not be used, but should be occasionally unrolled and turned. It will also sometimes occur that paper which has been at hand a considerable time, has been kept in some very dry cupboard, or place in which it may have shrunk below its ordinary dimensions: in this case, if lines were to be laid down to scale immediately on

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bringing it out, and the paper then left exposed to ordinary atmospheric influences, it would be found to have expanded, and on applying the scale to the lines previously laid down, it would be found that they now represented a greater length than was originally intended.

Some persons may think that these are unnecessary precautions, and that no appreciable error or difference arises from such causes, but such is far from being the case; when a plan is being made to, say, 2 chains to an inch, and the lines laid down are some of them from 20 to 30 chains each, it would then be no unusual thing to find a difference of 20 links and upwards in the longest lines, and this represents an error, multiplied over two or three such lines, sufficient in some cases to give rise to disagreeable consequences, and to law suits occasionally for infringements of boundaries, the costs of which are sometimes heavy.

This is only one of the many little points of detail which go to make up the difference between a good plan and a bad one,—between an accurate plan and an inaccurate; for with a material so absorbent of moisture as paper is, it is most natural to expect that in laying down long lines to scale, without giving any attention to the normal, or abnormal state of the paper, differences and errors are sure to arise and to accumulate.

Where the plan to be made is a permanent working plan the best paper should be procured, for inferior papers wear badly, and are easily chafed off with the action of indiarubber in the operation of cleansing them from the dust and pencil marks, which are the inevitable accompaniments of a mining plan; but an inordinate use of indiarubber only goes to destroy the face of the paper, and causes it to become the more easily soiled.

The best hot-pressed paper is considered the most durable, and best to work upon; and it should be well mounted either on white or brown cloth, and bound at the edges.

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CHAPTER II.

DIVIDING AND LINING THE PAPER.

HAVING given the paper sufficient time to season properly, the next thing that should be done with it is to carefully lay down two series of lines, dividing the paper into squares of, say, 10 chains each way, or 10 acres area each; one set of these lines should represent a meridian (which of the meridians it should be we will hereafter discuss), and the other set should traverse the first at right angles. This operation should be performed with scrupulous care, and to do it properly and accurately a large beam compass is necessary, and a long thin true straight-edge; if one of steel is at hand so much the better,—there are few things more useful and valuable to the surveyor.

If a hand compass (or ordinary dividers) is used to mark off on the two base lines (which a person of experience would at once recognise as the first step) traversing each other, it should be so set that it will accurately divide such a sufficient number of tens, taken together, as shall ensure the accuracy of each division; since it is, in a matter of this kind, unwise to trust to the setting of the compass to one single measure on the scale:—for instance, if a divided beam compass is used the hand compass should be passed over such a number of the multiples of the division determined on for the side of the squares on the paper, as shall ensure its dividing accurately over the length and breadth of the paper.

The lines should then be finely and truly drawn through the points so marked with faint red ink, or some other colour that will be sufficiently distinguishable from the other lines to be drawn upon the plan.

It will be necessary to determine, before the lines are laid down, what direction on the paper the meridional lines must take so as to ensure the plan of the property being got fairly

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into the body of the paper, or else the conformation of the outline of the boundary to the edges of the paper will never have a pleasing effect on the eye; this may usually be ascertained from some old plan, or by taking the bearing of some distant object with the theodolite from one of the angles of the boundary, or a combination of two or three such lines across the middle of the property. The correct laying down of these sets of lines is a matter of great importance, as instances are frequently met with where plans of properties of 300 or 400 acres area, or more are made, and the magnetic meridian is represented by a short line in one corner of the paper of about 14 or 16 inches in length; and to plot a series of lines at different points on the paper from this one meridional line is a matter of no little difficulty, and such an operation involves almost certain errors to a greater or less extent; for whether a rolling parallel ruler, or angle and straight edge are used (the latter being decidedly the most accurate) in the operation, errors under such circumstances cannot be wholly avoided; but with these rectangular and parallel lines the protractor can be laid down on the part of the map most convenient for easy plotting, and greater accuracy can be thus ensured. These lines are also useful in another way, for if proper attention has been paid to the preliminary work of the seasoning of the paper; and next, to the marking of the distances, these lines afford a ready gauge at all times, by applying the scale to them, to ascertain whether the Map has been left about in a damp place, and is unduly expanded with moisture; or whether from having been in a very dry and warm place, it has contracted below its normal dimensions.

We have noticed the fact that when a Map has lain open on the table in a warm sunlight for some time the contraction has been sufficiently marked to be distinctly appreciable in a line of 5 inches long; and thus it becomes wise to have regard to influences likely to affect, in a marked manner, the expansion or contraction of the paper.

By having the plan so divided into squares of 10 acres each they also assist the eye in forming a rough estimate of

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the quantity of ground exhausted of any particular vein—supposing the ground to have been worked regular and uniform; they also assist the computation, when a more accurate estimate is to be made.

CHAPTER III.

THE MERIDIONAL LINES.

In respect of the "Meridional" lines it has hitherto been generally, or, so far as we know, universally the practice to represent the *magnetic* meridian as the working base line of the plan, from which, at all subsequent times the workings or additions to the plan have been marked off; and this practice has continued in consequence perhaps of, first, a want of due consideration of the actual difference the magnetic variation really makes from year to year in lines of even moderate length; and, secondly, from an absence of a readily and simply adjustable instrument with which to take the angles with the differences corrected.

The western declination of the magnetic meridian is now decreasing at the rate of about 1° in 8 years, or about 7½ minutes per annum.

If we may suppose the case of a plan made, say, 8 years ago, with a particular instrument to take the angles, and that in the meantime no addition has been made to some particular part of it; but that now, from a resumption of mining operations or some other cause, an addition is to be made to it from surveys now taken; and if we further suppose a portion of the new workings to be a continuation of a straight engine plane, and that the part to be added measures, say, 850 links; and, further, if the length be laid upon the plan according to a magnetic angle taken *now* with the instrument, we shall find that instead of the present angle corresponding with the last taken 8 years ago, and so showing a continuous straight

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line, there will be a lateral deviation from a straight line to the extent of 14·83 links to the *left*, looking in the direction in which the extension has been made. But if it is an addition to be made after one year instead of eight years, during which time, at the ordinary rate of decrease, the deviation will have been 7½ minutes; and if the addition to the plan be, say, 630 links, the lateral deviation will amount to 1·36 links for this length; and when we consider that a mining plan is frequently being added to for 16 years or 20 years, and often more, the importance of taking the magnetic variation into consideration cannot well be disputed; for in 20 years the lateral extreme deviation in a line of 20 chains in length, would amount to no less than 87·2 links; and in the simpler case of a 12 *month's* work being added at one survey at the end of the year, and where the aggregate of the lines in one direction has been 9 chains, the accumulating error would amount to 1·96 links, or about 16 inches.

These things fairly considered it will readily be seen what an unsatisfactory base of operations the line of magnetic meridian really is, if treated as an *invariable* line, while it is, as a matter of fact, *constantly variable* and changing.

The plan of taking the angles with the magnetic needle is so general, and answers the purpose of a good mining plan so well, that it is not intended to say anything here in disparagement of its utility and general applicability; indeed we do not conceive that there is, at the present time at least, any other system known, that can be brought into successful competition with it. It is quite right and proper to be able at times to dispense with the use of the needle, when a surveyor is compelled by force of circumstances to fix the instrument in some locality likely to disarrange the polarity of the needle, and to interfere with its proper action, and in such cases it becomes absolutely necessary to dispense with the use of the needle; but we conceive it to be in such cases only that it is found advantageous to dispense with its use, for we hold that with a thoroughly good instrument used and handled with care—the needle being set each time

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to zero, and the angle being read on the verniers—the use of the needle affords the most correct results that can be attained in mining surveys, and thus the errors which are *instrumental* can be reduced to a minimum.

But as no instruments hitherto in common use have any adjustable zero to alter with the alteration of the magnetic meridian, either once or twice a year, as may be deemed necessary, it has been usual to set the needle to the common zero of the dial-plate, and to work from this line as though it was *invariable.*

Bearing in mind the foregoing facts, we advance the opinion that the meridional lines to be laid down on the plans should represent the *true* meridian, and not the *magnetic* meridian; and the second series of lines will of course cross these at right angles, and represent the East and West lines upon the plan.

The way in which we propose to provide for the adjustment of the instrument to the True Meridian, and the adoption of that meridian as the working base line instead of the magnetic meridian, will be found described in Chapter VIII. of the present treatise.

CHAPTER IV.

CHAIN, CHAINING, ETC.

THE proper handling of the chain is scarcely of less importance, in mining as in every other surveying, than that of the instrument; and it should not for a moment be supposed that the surveyor can delegate the affairs of the chain altogether to his chainmen.

It is of first importance to have the chain correct in length, and the stretching corrected regularly as found necessary. A correct datum for proving the chain should be at hand, and should frequently be resorted to, to ensure the detection of any extension that may have occurred. It is

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not sufficient that this should be done at stated periods, it should rather be done whilst bearing in mind the work the chain has been used in; for it will often occur that the chain will have been strained and stretched more with one or two days' operations in some bad place or ground, than in ordinarily good positions in as many months' use; and hence the chain should be tested whenever there is reason for suspecting it necessary, in fact, it should be done often, so that the surveyor may be assured of its accuracy at all times.

This having been done, it should be constantly kept in mind that no amount of care exercised in the taking of the angles with the instrument will compensate for a want of care in taking the lengths of the lines; for a correct angle and incorrect line, or *vice versa*, cannot possibly go to make up a correct plan; hence, however good an assistant the surveyor may have to take the chain-lengths, he should never wholly lose sight of the work himself, but should always give such an amount of attention to it as would ensure a constant diligence in his assistant, to take off the true lengths of the lines; for, especially in underground work, if the chain is very dirty, the difficulty of recognizing the divisions is greatly increased; and, in the like proportion, the vigilance necessary to obtain the correct lengths. As arrows can seldom or never be used underground, the assistant that draws the chain forward has to supply the substitute, in the manner of marking the chain-ends; and as this man will generally be found to be a man picked up in the colliery or mine for the occasion, and with no particular idea of chaining, or any appreciation of the necessity for nicety in marking the lengths, the greater is the danger that it will be thought by him sufficient if he marks somewhere within three inches of the proper place. We have generally found it necessary to give this leading man a short lesson before commencing operations, with the view to ensure his attention and care: and we have found the most accurate way to mark the ends of the chain to be, to cause the leading man, after he has drawn the chain

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forward the whole length, and has been put properly into *line*, to turn around to face the man at the other or "following" end of the chain; and having strained the chain properly into line, to bring the *toe* of his right foot to the handle of the chain,—the handle being held edgewise, and the foot being placed wholly on the ground; if this be carefully done there can be no error so far. Note is then taken of any headings, stalls, faults, threads, soft or inferior coals, commencement of solid rib, or of gob, or of any other thing on the way requiring to be booked down, and the man at the "following" end then walks forward and places the toe of his right foot to the toe of his companion, who then again proceeds forward another length, and the hindmost handle of the chain being brought and held to the toe of the foot the chain is again properly strained, set in line, and again brought to the right toe of the leading man, and so on to the end of the line. Where this is regularly and carefully done, there need be no error of practical moment occurring in the operation of chaining.

Where arrows are and can be used, the number we have found to be best is *eleven;* by using eleven there is always one in the ground, ten being given up to the leading man when the eleventh has been put into the ground, and it thus becomes the first in the next ten. This we think to be better than walking forward when the tenth has been put into the ground, and then draw it out, so that it may be given up with the nine others, and the place of the tenth marked with the foot, as in this way there is the position of the tenth always without its permanent mark: and so great is the convenience of using eleven arrows instead of ten, that we conceive the practice would at once commend itself to any surveyor who should determine to adopt it in preference of using ten only.

It is occasionally found very convenient and advantageous, when chaining over land on which long coarse grass, rushes, or other tall plants are growing, to have a strip of coloured cloth or a small white flag fastened into the handle eye of the arrows, so that they may be the more readily distinguishable amongst the tall herbage; and the practice in such cases affords

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a means of frequently expediting the work, in avoiding the loss of time which would sometimes be taken up in searching for the arrows, and enables the eye to catch them readily.

CHAPTER V.

FIELD-BOOK.—ENTRIES, POINTS, ETC.

THE method of keeping the surveying book is a matter deserving of more attention than is often given to it, and a looseness or otherwise in this part of the operations indicates, more or less, the kind of attention bestowed on the business generally.

There is a divided practice in the matter of ruling the Field-book, some using two lines within which to write the chain-lengths, &c., and another and less general method is to have one line only,—this line being an ideal representation of the line chained, and the different lengths being written on it. We must give a decided preference to the latter method, as we have found it more generally convenient to have one line only than two; and in this method the sides of the book are left more clear and open for drawing such lines as may be necessary to illustrate the figures entered down; and the sketching can be more clearly done than when two lines are used.

In underground surveys, having the book lined ready, and being assured of the correct length of the chain, and having an instrument of good quality, the surveyor having selected the first position to set the dial, will carefully level the same and set the needle to zero after it has become steady; and before taking the angles the needle should be disturbed by a slight tap on one of the legs of the stand, or, which is quite as well, by lifting the needle off the pivot with the "rest-piece," and lowering it again, so that it may be seen if it will again return to zero, and if it does the reading off the angle may be proceeded with; if it does not return correctly to zero it should be again slightly disturbed, and if it still varies the first setting

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was not correct, or something attracts it, and the zero should be moved a little so as to meet that point at which it will permanently set. The limb will now be worked around so that the light may be correctly seen through the sights, and this being done the angle will be read off and entered in the book, with the number of the line set under it: if the limb has two verniers so much the better (in fact any instrument fit for correct surveying is not without two), and these, divided either to 1′ or 3′, the former being much the best, will enable the angle and its opposite reading to be both taken; and we hold to, and strongly recommend to others, the practice of entering the readings of both verniers in the book, and after they are entered add 180° to the less (mentally), or subtract 180° from the greater reading, and if the sum or difference, as the case may be, makes the other reading as entered in the book, the angles may be considered as correctly entered. Some may think this to be quite unnecessary, but we hold it to be not so, as without it there is no check upon the correct reading of the angle; and there is no person practising this method but will at times find that an error has been made in entering either one or the other of the readings; and without the system of check there would be no certainty, and perhaps no probability, of the error being discovered in time to correct it; but when the two readings are entered, and their difference then computed, there is a strong safeguard against error in this respect.

The two angles of the first two lines having been taken, and the chaining proceeded with, notes are made of anything in the way of headings, faults, or other things occurring in the route, so that the book may be a correct representation of all that will be necessary to be shewn upon the plan: the instrument is then moved forward to beyond the light of the second line, and the operator having gone so far as the back light can be clearly seen, the instrument is again set up, and the operation of setting repeated as before described, and the lines again taken, and so on in succession.

It should be a maxim in working that nothing should be left to memory that can be entered down in the book, for when that is practised the memory will occasionally be overloaded,

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and confusion of things will ensue, and error will be the consequence: therefore all things required to be put upon the plan should be distinctly entered in the book, in such order that were it to be put aside for seven years, and then taken up for the purpose of making a Plan of the work described therein, there would be no difficulty in following the particulars entered, and of making a correct plotting of the same.

An abrupt turn to one side or the other will require a mark to indicate the direction in which to continue the plotting or else it may be as natural under certain conditions to think it should be continued in one direction as the other: for the purpose of indicating the change in direction we recommend the making of a mark thus <——— , under the figures (for instance <—9—) giving the number of the line *commencing at the turn.* The horizontal line is simply that line which is drawn between the figures expressing the *total length* of the preceding, and the *number* of the succeeding line; and the mark either < or > indicates,—the former a turn to the *right* and the latter a turn to the *left*, it being in the latter case placed on *the right* of the horizontal line, and in the former case on *the left.* This mark must not be confounded with the *arrow* or else it will mislead: thus, the mark <——— , here recommended, indicating a turn to the right, and ———> indicating a turn to the left, may, if made into arrows thus <——— , or ———> , be made to indicate the opposite; but no difficulty on this head will arise when the distinction in the marks is remembered;—the idea being that the point joining the two short lines of the mark <, or >, represents the *position of the instrument* in reference to the two adjoining lines, and the short lines meeting in that point shew the *relative directions* of the lines so meeting, of which they are the representatives.

Note must also be taken of the "rise" or "pitch" of the measures in which the chaining is being done, so as to allow for the same, and to eliminate the true horizontal measure.

An example is given on Plate 4 of a book made upon these principles, with some descriptive entries, and a plotting of the same for the guidance of students.

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It will sometimes occur that a survey is required to be made so as to give "points" to headings being driven towards each other, from distant parts of the workings, and it may be of great importance that they should meet well in line, not only to save the cost of driving about (perhaps in hard ground) to get "loose," but to ensure the working being subsequently usable for a heading, engine plane, or some other important work; or it may be to find the relative position which a proposed pit, either for air or otherwise, occupies, or where it will come down when sunk from some overlying measures or veins; or it may be to ascertain the proper position and direction for a drivage into a pit in some measures through which the pit has passed, for drainage or for ventilation: in these and similar cases it will be advisable to make an entire survey around, from one face of the work to the other, or so far as it is practicable to go; and in such surveys it will seldom be necessary to make notes of anything particular on the way, except for the purposes of a check at a few points. These lines will require to be plotted with great care, so as to be able to determine the "point" that will have to be given to the drivages, so that they may meet well. It is in such cases and similar to these, that the method of working out the line of survey by the Traverse Tables is so important, and of such utility; for if the survey has been correctly made, and the lines worked out by the Tables, the *terminal* positions can be determined with much greater accuracy by this combined operation than by plotting. We would not indeed recommend that the plotting should not be done; but where the survey was both worked out by the Tables and plotted, and some little difference resulted in the two methods (which may certainly be looked for), we would unhesitatingly give the preference for accuracy to the result obtained by the Tables. If the difference should be very considerable there may be some error either in the plotting, or in the taking out the figures of the Tables, or in not placing them in their proper columns, and a search should be made to discover it, so that the greater confidence may be given to the result obtained. But we have had a difference between

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the plotted and the computed plan (or the terminal points of such plan) of considerable length, of upwards of 30 links; and having failed to discover any error in either the operation of plotting, or working by the Tables, we have decided in favour of the result obtained by using the Tables, and have found the center of the sinking (the matter in hand in that case) to come down within two feet of the mark made for it, although the *route* of the survey lay through very crooked and uneven ground, and through a pit from one measure to the other. This is not given as an unusually good result, for better could be added, but only as a proof that had the plotted survey been acted upon—although it was laid down with the greatest care—instead of the result obtained by the Tables, the error in this case would have been considerable; but as a rule the difference would be less, except in long and difficult surveys when it would perhaps be even more. And it is only what would justly be expected in such cases, if we consider the method of computation to be more correct than plotting could possibly be; for there are no thick compass points, no little accumulating errors in the setting the lines from point to point, the thickness of pencil lines etc., but the rectangular co-ordinates of each line are joined by absolute mathematical points.

If the opposite drivages are to be a heading or drift in hard ground, instead of following a vein of coal or other mineral, it will then be necessary to "level" the headings around from one point of driving to the other, so that the difference of level may be also known, and the "pitch" the new drivages are to be set to, worked out. The miners should then be supplied with teebobs, inclined to the proper angle at the foot, with which they should set the plates or rails of their roads; and as this is only an approximation to the true pitch, the surveyor should take his Spirit-level and try the accuracy of the floors occasionally, as well as examine the "points" by the dial, to ensure against error in either pitch or points.

Great caution should be exercised in making use of timber for holding the points; it will often happen that in con-

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sequence of one side of the heading being a little "tighter" than the other, at the place where timber has been selected to hold the point marks, the squeeze of the ground will cause a slight (and sometimes a considerable) lateral movement in one or both of the colar pieces so selected; and possibly they may have motion imparted to them in opposite directions, as is frequently seen; and if such should occur to two colars used for carrying the "point," or even to one of them, the consequence may be serious if not detected in time to rectify the error. Therefore the solid ground should, if possible, carry the points, even if it should be necessary to stand timber for the sole purpose of preventing the roof scaling off, or for supporting the ground from falling while the drivages are in operation, or until the "points" can be moved to more secure ground.

In moving "points" forward great care should be practised, so as to ensure the continuance of the work in the desired alignment. If it is a drivage going to meet another coming from the other side, or a single drivage going to some particular position in some workings ahead of the new heading, the instrument should be used to move the "points" forward when it becomes necessary: and the dial being placed under the first of the former point-marks, others can be set up near the face of the workings for further guidance; or, which is better, a mark should be put at about every 30 yards along the heading or drift, and from these the men should try their work. It is much more sure to drive with points 30 yards apart, if they are carefully put in position, than with those at 10 feet apart; and in the former arrangement it is only necessary to shift one mark at one time, and they are always within easy reach of the workmen.

When two marks are to be shifted forward to the "face" without the application of the dial, the accuracy of the new marks should be carefully tested; and to do this proceed by setting up the new points near the face by plumbing marks to the roof, from lights put in position by looking through the original mark lines: then, first, have a light placed in the "face," by using the *original* mark lines; next, by using the

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new lines see if they and that in the "face" still coincide (which they should do); next, take *one* of the old lines and *one* of the new, and again see if they coincide with that in the "face"; if they do this last operation will be a proof that the new lines will correctly continue the alignment given with the old lines, and the marks will have been correctly shifted.

As to the kind of appliance that is best for holding the *light*, we may remark that we have found it the better way to have no appliance at all for suspending the light, but simply to weight the cord, soundly fastened to the roof, sufficiently to draw it out straight and free from kinks. If then the light be held right in front of it, if marks 30 yards distant be used; or by the side and at two inches from it, if the marks are about 10 feet apart,—for at the latter distance the string itself will be plainly visible with the candle two inches off,—the arrangement will admit of very easy and correct working.

If however safety lamps are exclusively used, and open lights are inadmissible, it is then better to suspend the safety lamps from the lines by their handles, and use them in that way to move the mark forward; but in all cases more care will be necessary in driving with safety lamps, than with free lights, as it is more difficult in that case both to "try" and also to keep the point.

The benefit which should and would result to the employer or owner, as well as the satisfaction felt by the surveyor at seeing the work "meet" correctly, will more than compensate for what some may be disposed to look upon, but which we do not, as excessive nicety in the matter of "points" and "pitches"; and not only in these matters, but in every other matter connected with correct surveying, it is the attention to the small details, and the care with which they are executed, that make the difference between a good plan and a comparatively worthless one: for even mining surveying (the roughest-done work of any perhaps in the way of surveying) consists in something more than in being able to tell, within an half degree, the division on the dial to which the needle points, though this is often looked upon as all that is necessary to

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enable a person to survey a colliery; but the "snakelike" contortions and windings often to be met with in collieries and mines, as the consequence of not being able to get opposite drivings *loose* in the way they were intended to meet, testify to the rough off-hand methods too often practised, as well as to the expensiveness of such a class of surveying.

CHAPTER VI.

TRAVERSING.

HAVING passed in review the field-book, setting of the dial, reading off the angles, taking the notes, and other things necessary to supply the data and particulars requisite to the making of a correct plan of what will be met with in the mine or colliery, we will next proceed to show what entries are requisite and essential, in order that the Traverse Tables may be used in the computation of a survey.

In the first place we will refer to the accompanying diagram, No. 1, and would recommend a very careful perusal of the whole of the lines comprising the same, and especially of the red lines, and the directions in which the "arrows' point. Let it be supposed that the positions *A* and *B* represent two pits or other objects, and that the black lines represent the lines chained in passing, in the operation of surveying, from *A* to *B*; note also the direction of the meridional line with its transverse axis, and the point that represents the north. The black lines 1, 2, 3 will be observed to go nearly eastward; lines 4, 5, and 6 nearly northward; 7, and 8, have a northern departure from the west, and 9 goes to the south of west; 10, 11, and 12 then go nearly to the north; 13 goes nearly east, and 14 nearly southward. Now it is possible to define the relative positions of *A* and *B* without plotting the lines at all, by the use of the Tables, and the simple operations of addition and subtraction.

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In conjunction with each black line representing the chained lengths, will be noticed two red lines, each containing an arrow, and forming with the black line a right-angled triangle. All the *red* lines parallel with the *meridian* line of the diagram are represented by figures in the columns of the Tables headed Lat. (a contraction of "Latitude") and Per. (a contraction of "Perpendicular"), and their values will be taken out from that column; and all red lines parallel with the *transverse* axis of the meridian, being parallel with the equatorial line, are represented by figures in the columns headed Dep. (a contraction of "Departure"), and Base, and their values will be obtained from those columns. Next observe that some of the arrows in the red lines parallel with the meridian point to the North, and some to the South, accordingly as the line to which they stand points northward or southward of the east and west line that may be conceived to pass through the zero or starting-point of the line in question, of the diagram: some of the arrows parallel with the equatorial line point eastward, and some point westward, accordingly as the line to which they stand points eastward, or westward of the corresponding ideal meridian line. Now if we first take the equivalents of the red lines parallel with the meridian, and separate those pointing to the north from those pointing to the south, or, which is the same thing, place them in separate columns, and take the total of each column, we shall see in which direction the working has progressed by observing which column has the higher total; and if the less be subtracted from the greater, the difference or resultant will be the actual distance between the two terminal points, *taken in a line parallel with the meridian.* Also it will be similarly observed that of the lines parallel with the equator —some pointing to the east, and some to the west—if we separate the equivalents of these into distinct columns as we did the other, and take the totals of each, and their difference, we shall find what is the resultant sum of the progress in a line parallel with the equator, and whether it has been to the east or to the west.

These two differences will now give the data with which

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to define the relative positions of *A* and *B*. Making a mark to represent *A*, and from this mark drawing a straight line of sufficient length to enable us to prick off on it by some scale (any may be chosen) the first found difference, make a fine and distinct mark; then with a set square or other accurate instrument, draw carefully at right angles from this point a line, either to the right or to the left as required by the *second resultant*, and on this line mark off with the same scale as before the second difference; this distance from the first line will be the position of *B*. The former of these lines will be a north and south line, and the latter will be an east and west line; thus the required relative positions are determined, and the lines with which it is done form the perpendicular and base of a right-angled triangle.

The thorough digestion of the remarks and explanations here given, in reference to the diagram and its several lines, will make the apprehension of what follows comparatively easy; and it is essential that it should be thoroughly understood, before proceeding to attempt to work out any series of lines by the Tables.

Traversing Entries in Field Book. The next thing will be to shew how the angle is to be entered in the book, so that there may be no difficulty in easily determining the proper reading.

The plate forming the *bottom* of a dial is usually divided and figured in each quadrant distinct, from 1^0 to 90^0; two quadrants commencing to reckon from the *N.* point in the box, and two commencing at the *S.* point; two finishing at the *W.* point, and two finishing at *E.* This division of the circle into quadrants shews at once, in their respective initial and terminal points of division, *the points from which*, and the *direction in which* each quadrant must be read, in order to the workings being computed by the Traverse Tables.

The first quadrant therefore, embracing the horizon from north to east, will be read *from* north *to* east; the second quadrant, embracing the horizon from east to south, will be read *from* south *to* east; the third quadrant, embracing the horizon from south to west, will be read *from* south *to* west;

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and the fourth quadrant, *from* north *to* west. This must be the *invariable practice* for traverse working, and where the readings cannot be obtained from the verniers, as they cannot be in more than the first quadrant, the angles must be carefully computed: and for this purpose the readings should be severally entered in the surveying-book as before described, as though it was intended to make use of them in plotting a survey as ordinarily: then, the traversing angle in the first quadrant will be the ordinary reading of the instrument; the traversing angle in the second quadrant will be the difference between the ordinary reading and 180°, thus 100° 42′ in the ordinary reading will be 79° 18′ for traversing, and 146° 27′ in the ordinary reading will be 33° 33′ for working by the Tables; the traversing angle in the third quadrant will be the ordinary reading of the instrument, *less* 180°, thus 212° 30′ in the ordinary reading becomes 32° 30′ for traversing, and 254° 12′ will become 74° 12′ for working by the Tables; and the traversing angle in the fourth quadrant will be the difference between the ordinary reading and 360°, thus 293° 45′ will become 66° 15′ for traversing, and 357° 21′ will become 2° 39′ for working with the Tables; and so on of all other angles, in whichever quadrant they may be situate. There is here no great difficulty in comprehending this part of the matter clearly, close diligence and thought being only necessary.

The next thing to be mastered is the *description* to be given in the traversing to the *co-ordinates* of each line: by the description to be given them is to be understood the entering with each angle distinctively whether its co-ordinates are a northing and a westing, or a southing and a westing; a southing and an easting, or a northing and an easting. Thus the angle in the first quadrant (remembering the order given in the instructions above in reference to the angles) will have a northing and an easting for its co-ordinates; the angle in the second quadrant will have a southing and an easting for its co-ordinates; the angle in the third quadrant will have a southing and a westing for its co-ordinates; and the angle in the fourth quadrant will have a northing and a

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westing for its co-ordinates; and these rules hold good for every angle in the respective quadrants in succession. Of course if the line should be *exactly* due north, or due south, it will neither have an eastern nor a western co-ordinate, but it will be a northing or a southing entire, without reference to the Tables at all; and in the case of a due east or a due west line, there would be no northing or southing co-ordinate, but the line would be an entire easting or westing as the case may be, without any reference to the Tables, the lengths of the lines to which they refer being entered in full.

These explanations and instructions embrace the whole that need be said to enable any person of ordinary intelligence, and who will try, to understand the theory and practice of working with the Traverse Tables; but the instructions here given should be thoroughly mastered, so that the Tables may be correctly worked, and errors avoided in the operation.

The entry of the particulars for traversing should be made upon the same sheet or leaf of the field-book with the ordinary entries, and will simply consist of the number of the line, the traversing angle, the initials of its descriptive co-ordinates, and the total length; and these can be placed in the side of the book, as in the example we give herewith of a field-book, with both entries placed in juxtaposition.

CHAPTER VII.

THE TRAVERSE TABLES: THEIR CONSTRUCTION, AND APPLICATION.

THESE Tables were constructed by the author some years ago for use in his professional duties, and they are based on the same principles as the Traverse Tables for seamen's practice as given in "Hutton's Mathematical Tables." It will however

be found, on reference to that book, that the Tables there given are worked out for degrees and quarter-points only, and to radii from 1 to 10; and as a Table not less minute than this is inapplicable to surveying we determine to proceed to the construction of tables to every 3 minutes of the quadrant, and to 10 different radii of hundreds, commencing with 100, and ending with 1000. It will be readily seen that thus constructed the Tables are applicable to any base of measurement, either English or Foreign, that may be most convenient; it may be a link, foot, yard, furlong, mile, metre, kilometre, or league, in fact any measure desirable or necessary; but it is of course requisite that the measure of the *angle* should be taken according to the *English* system of 90 degrees in the quadrant, and 60 minutes in the degree.

The figures in the Table, and the positions of the decimal points, are applicable to the lengths represented at the top and bottom of each pair of columns, and marked "Dist."; these are each hundreds. But the computations are perfectly correct and applicable if the "Dist." is multiplied by 10, or considered as thousands; and when this is done it is only requisite to shift the decimal point as in the Tables, or conceive it to be shifted, one figure to the *right*, when the result will be obtained true to one place of decimals. If the "Dist." be *divided* by 10, the figures as in the Tables will in like manner be divided by 10 by shifting the decimal point one figure, or conceiving it to be shifted, to the *left*; and if divided by 100 (say by counting 600 as 6) the figures as in the Tables will be in like manner divided by 100 by shifting the decimal point *two places* to the left: hence the Tables are applicable to the computation of the co-ordinates of a line of any measurement or length whatever, from 1 link to 100,000 links, or from 1 metre to 100,000 metres, or kilometres, or miles. The Tables being computed to every 3 minutes of the quadrant will in general be sufficiently minute for all classes of surveying; but in the case of very long lines, if it should be found or thought necessary to obtain the co-ordinates to a single minute, it can be done to very near the truth (even when the decimal point is moved one figure to the right) by

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interpolation, taking either $\frac{1}{3}$ or $\frac{2}{3}$ of the difference as may be required, between those two lines of figures within which the angle to be computed lies (in doing this remember that the co-ordinates of each line *increase* in opposite directions, one increasing down the column, and the other up the column).

The degrees from 1^0 to 45^0 will be found along the top, and the minutes down the left side of the tables; and from 45^0 to 90^0 the degrees will be found along the bottom, and the minutes up the right side of the Tables, as in Trigonometrical Tables generally. If the angle therefore is less than 45^0 it will be found at the top and left side of the Tables, and the proper order for tabulating the co-ordinates of the angle will likewise be found at the top; if the angle is greater than 45^0 it will be found at the bottom and right side, and the order for tabulating the co-ordinates at the bottom likewise.

Thus, if we wanted to find the co-ordinates of a line 600 links in length, and whose $\angle$ is $33^0\ 42'$, we have on the page for 33^0 and on the line for $42'$ the quantities sought; viz—Per. = 499·17., and Base = 332·90; also, if we want the co-ordinates of $\angle\ 56^0\ 18'$ (or the comp. of $33^0\ 42'$), and a line of the same length as before, we have Per. = 332·90, and Base = 499·17;—being the same figures as by the first operation, *but with their relative positions reversed.*

If the lines had been each of them 666 links, instead of 600, we should have had in the first case, viz. $\angle\ 33^0\ 42'$ and Dist. 666, as follows.

Ex. 1.

	Per.		Base
600 =	499·17	and	332·90
60 =	49·92	„	33·29
6 =	4·99	„	3·33
Totals.	Per. = 554·08		Base = 369·52

And in the second case we should have $\angle\ 56^0\ 18'$ and Dist. 666.

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	Per.		Base
Ex. 2.	600 = 332·90	and	499·17
	60 = 33·29	„	49·92
	6 = 3·33	„	4·99
	Totals = 369·52	and	554·08

Again, suppose the case of ∠ 20° 39′, and Dist. 745 ; then look along the Tables until you find 20° and down the left side to 39′, and on that line take out the figures for 700, 40, and 5 respectively, thus :—

Ex. 3. Angle 20° 39′, and Dist. 745.

	Per.		Base
	700 = 655·02	and	246·86
	40 = 37·43	„	14·11
	5 = 4·68	„	1·76
	Totals = 697.13	and	262·73

Take one more example. ∠ 76° 45′, Dist. 1789 links. In this case the degrees will be found along the bottom, and the minutes on the right side thus :

	Per.		Base
Ex. 4.	1000 = 229·20	and	973·38
	700 = 160·44	„	681·36
	80 = 18·34	„	77·87
	9 = 2·06	„	8·76
	Totals = 410·04	and	1741·37

The foregoing examples will clearly indicate the methods of taking out the co-ordinates for traverse surveying.

It will be perhaps advisable to draw attention to the last example, and to point out that in consequence of the Tables having computations for 1000, no shifting of the decimal point is called for in this case in reference to that number ; but for every 1000 above the first there will be a shifting of the decimal point ;—for instance, the co-ordinates for 2000 will be found in the columns for 200, with the decimal point placed

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one figure to the right, and so on for the others as each case may require.

It should also be the invariable practice to place the figures coming under the designation of "Per." *first* in position, as they are above, and those coming under the designation of "Base" *last*. It should also be remembered to consider the co-ordinate designated "Per.", as that ordinate *parallel with the meridian;* and the co-ordinate designated "Base" as that *parallel with the equator:* by following these instructions there will be no confusion of the co-ordinates, nor any misconception of the true positions for the termini to be described from the results obtained.

We will now adduce proof of the foregoing examples by working out corresponding results by the ordinary rules applicable to the computation of right-angled trigonometry, as in the following.

RULE: *Add the logarithm of the given side to the sine of the angle opposite to the side required, and from the sum subtract the sine of the angle opposite to the given side: the remainder will be the logarithm of the side required.*

Bear in mind that the sine of the *angle of the traverse* is the co-ordinate "Base"; and the sine of its complement, the co-ordinate "Per." (or "Perpendicular").

The sine of 90° being equal radius—the angles treated being all right angles—we have

One proof of Ex. 1. (giving the "Base")

As Rad.....	=	10·0000000
: log. of 666	=	2·8234742
:: sine ∠ 33° 42′.....	=	9·7441712
: log. of 369·25	=	2·5676454

Also one proof of Ex. 2. (giving the "Base").

As Rad.....	=	10·0000000
: log. of 666	=	2·8234742
:: sine ∠ 56° 18′.....	=	9·9200994
: log. of 554·08.....	=	2·7435736

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Proofs of Ex. 3.

As Rad. ..... = 10·0000000

: log. of 745 ..... = 2·8721563

:: sine ∠ 20° 39′ ..... = 9·5473542

: log. of 262·73 ..... = 2·4195105

and As Rad. ..... = 10·0000000

: log. of 745 ..... = 2·8721563

:: sine ∠ 69° 21′ ..... = 9·9711608

: log. of 697·13 ..... = 2·8433171

Proofs of Ex. 4.

As Rad. ..... = 10·0000000

: log. of 1789 ..... = 3·2526103

:: sine ∠ 76° 45′ ..... = 9·9882821

: log. of 1741·37 ..... = 3·2408924

and As Rad. ..... = 10·0000000

: log. of 1789 ..... = 3·2526103

:: sine ∠ 13° 15′ ..... = 9·3602154

: log of 410·04 ..... = 2·6128257

These proofs shew the construction of the Tables, as well as supplying conclusive evidence of their accuracy, and of the accuracy of the method employed in the operation of extracting the co-ordinates for the different angles, and length of the lines.

There is nothing new in the proposal to apply these principles to surveying. They were, so long ago as A. D. 1635, applied by a Mr Norwood to lines and angles taken with the circumferentor over the public road from York to London, and the difference of latitude of those two cities determined by him, very nearly, from the traverses; and proposals have been made to apply the principles to the planning of large estates; but, so far as the author knows, there have been no

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other Tables so far issued, so well calculated as these are to render the application of these principles to surveying both easy and general,—computed as these are to a degree of minuteness sufficient for all practical purposes of correct surveying, and their application duly explained in the accompanying letter-press.

There is no reason why these principles should not be applied extensively to mining surveying; for in large and overlying mining operations there are cases continually arising where it is required to sink from one vein of mineral to another, for ventilation or some other purpose; also to drive from one part of the workings in some mine or colliery across the measures to another; and also when driving in both directions it is highly important that the points given to the drivages should be correct; and sometimes it is required to drift at a more or less steep pitch from one measure to another; and in such operations, when the work proceeds in both directions at the same time, the question of the cost, as well as the matter of convenience, depends greatly upon good surveying and correct points; and it is such cases as these that really put the skill of the surveyor to the test, and they are also those cases in which the application of the principle of traversing is found to yield the most satisfactory results. But cases arise also where it is desirable to ascertain if the boundary has been reached, at some point very remote from the Pit, or level mouth; and sometimes it will require a series of lines of somewhere between 60 and 100 (perhaps more) to reach the supposed position of the boundary: then the survey should be taken with great care, and the application of Traversing should be adopted in such a case, as being much more conducive to accuracy than plotting can be from the same data.

It will likewise occur frequently that in a long underground survey there will occasionally be a prominent turn in the general bearing of the workings; perhaps the general bearing so far has been nearly westward, and at a particular part the direction alters, and the bearings are somewhere to northward. It is very desirable that the point where the change of direction occurs should be very carefully marked down from the traverses

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first, and also the terminal point; the plotting should then be proceeded with, and the plan so made should be brought as near as possible at those corresponding parts to the points marked from the traversing computation; and where a little difference is found to have accrued, preference should be given to the traverse points (always bearing in mind that care should be observed to ensure accuracy in taking out the co-ordinates).

If it is suggested that this double operation is unnecessary, and that plotting is sufficient without traversing, we can confidently assert that bad and loose surveying is exceedingly expensive; and that there is no system so conducive to true economy as accuracy, and this cannot be attained without due measures being adopted to ensure it.

The chief utility of the Traverse Tables in surface surveying is the facilities they afford for reducing the principal lines across an estate to one pair of rectangular co-ordinates, and thus increase accuracy.

Although it is still the practice with many surveyors, in making a survey of a property, to make a circuit of the boundary by taking a great number of short lines according to the bends, or outline of the limits of the property,—making these short lines the ground-work of the survey from which to construct the map,—and especially where there is but little more than the boundary to lay down; but it is about the worst system that can be followed, and often results in the production of a Plan not worth the labour expended upon it.

The salient angles in the boundary of the property to be surveyed should first be selected by the surveyor, in sufficient number to enable him to devise such a system of main base-lines and triangles across the property as shall enable him to fix all those points, as well as a sufficient number of objects within the boundary on his Plan, with absolute certainty, by Traversing, or Trigonometry, or both combined, as circumstances require: the intervening lengths of the boundary should then be surveyed by a combination of straight lines and triangles, according to the conformation of the boundary line; and in all cases running the straight lines *where practicable* from one salient point to another, and filling in where neces-

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sary with diverging lines to meet bends, and which divergence may be measured as a check with a sextant. In this way, if errors have been committed at any point they are almost sure of being detected, and their locality known; and if they arise between some two of the points selected, they cannot affect the accuracy of the next section; and all the internal objects will be easily taken, in connection with the different internal stations of the triangulation.

As scarcely any two estates are of similar outline, or are affected by similar conformations, so the same system of lines will seldom be found perfectly applicable to any two surveys, and hence the judgment and experience of the surveyor must in each case be relied on to guide him, in the selection of that system which will involve the least amount of labour combined with the greatest amount of attainable accuracy.

Where the estate is tolerably level the selection of these lines, and their measurement, do not present much difficulty; but where the country is mountainous, and steep escarpments have to be crossed and measured it is different, and careful means have to be then adopted to ensure accuracy. Where it appears to be indispensably necessary to have a line, either as a principal, or as a check-line, up a steep and rugged rise, it will generally be found more accurate and preferable to obtain the true length of the line by the application of trigonometry; and which will probably be best accomplished by selecting two stations in the plain, one of which shall be the end of the line to be measured (or even an intermediate point in it, if it is thought to answer the purpose better than the end), and between which and the other station in the plain the ground must be favourable for *correct chaining*,—each visible from the other, and from another station on the top of the hill, which may be the other end of, or an intermediate position in, the line to be measured, and to be selected on favourable ground, from which correct chaining may be continued. The three angles of this triangle should be correctly taken with an accurate instrument, and their sum should equal 180°; and the line in the plain to be measured should be gone over carefully twice, so that the first result may be checked. Then,

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by applying the rule of trigonometry previously given in this chapter, the correct horizontal length of the ascending line can be easily determined; and this length should be substituted for the length found by chaining, as being more correct, (even though the horizontal measure may have been procured as near as practicable), and therefore entitled to the preference. If this is a line forming one of a series, for the purpose of determining the positions of the *salient points of the boundary only*, the *chaining* of it will be unnecessary.

When it is thus determined to have a few triangles over the property, to determine the position of the salient points, from which to form the ground-work of the Plan, one base-line should be measured on the most favourable ground obtainable near one side of the property; this should be the "base of computation," on which all the calculations of the Triangulation shall be made; and on the opposite side of the

TRAVERSING COMPUTATION. No. 1.

No. of the line.	Quadrant where found.	Traverse Angle.	Designation of Co-ordinates.		Length in Links.	Perpendicular.		Base.		Remarks.
						Northing.	Southing.	Easting.	Westing.	
		° ′								
1	1st	78·26	N.	E.	208	41·71	...	203·78	...	
2	2nd	76·42	S.	E.	354	...	81·43	344·50	...	
3	1st	3·46	N.	E.	246	245·47	...	16·15	...	
4	4th	5·34	N.	W.	208	207·02	...	...	20·17	
5	do.	11·48	N.	W.	349	341·62	...	...	71·37	
6	do.	15·00	N.	W.	540	521·60	...	...	139·76	
7	do.	81· 9	N.	W.	240	36·92	...	...	237·14	
8	3rd	85·30	S.	W.	320	...	25·10	...	319·01	
9	4th	61·33	N.	W.	528	251·53	...	...	464·22	
10	1st	3·00	N.	E.	340	339·53	...	17·79	...	
			Totals are =			1985·40	106·53	582·22	1251·67	
			Subtract			106·53			582·22	
			Nett results			1878·87 = Northing.			669·45 = Westing.	

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property the best line possible for correct measurement should be chained, as a check upon the trigonometrical computation. This will be called the "base of verification," and if the angles

The following will exhibit the operation of taking out the above co-ordinates in succession.

(1) 78°·26′ and 208			(2) 76°·42′ and 354			(3) 3°·46′ and 246		
Dist.	Per.	Base.	Dist.	Per.	Base.	Dist.	Per.	Base.
200 =	40·11 −	195·94	300 =	69·01 −	291·95	200 =	199·57 −	13·13
8 =	1·60 −	7·84	50 =	11·50 −	48·66	40 =	39·91 −	2·63
			4 =	·92 −	3·89	6 =	5·99 −	·39
208 =	41·71 −	203·78	354 =	81·43 −	344·50	246 =	245·47 −	16·15

(4) 5°·34′ and 208			(5) 11°·48′ and 349			(6) 15° and 540		
Dist.	Per.	Base.	Dist.	Per.	Base.	Dist.	Per.	Base.
200 =	199·06 −	19·40	300 =	293·66 −	61·35	500 =	482·96 −	129·41
8 =	7·96 −	·77	40 =	39·15 −	8·18	40 =	38·64 −	10·35
			9 =	8·81 −	1·84			
208 =	207·02 −	20·17	349 =	341·62 −	71·37	540 =	521·60 −	139·76

(7) 81°·9′ and 240			(8) 85°·30′ and 320			(9) 61°·33′ and 528		
Dist.	Per.	Base.	Dist.	Per.	Base.	Dist.	Per.	Base.
200 =	30·77 −	197·62	300 =	23·53 −	299·07	500 =	238·19 −	439·61
40 =	6·15 −	39·52	20 =	1·57 −	19·94	20 =	9·53 −	17·58
						8 =	3·81 −	7·03
240 =	36·92 −	237·14	320 =	25·10 −	319·01	528 =	251·53 −	464·22

(10) 3° and 340		
Dist.	Per.	Base.
300 =	299·59 −	15·70
40 =	39·94 −	2·09
340 =	339·53 −	17·79

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have been taken and the sides calculated, each correctly, this last measured line should not differ from the computed length more than from 2 to 3 links. This satisfactory result being obtained (and with instruments of the best construction for taking the angles a nearer agreement is quite possible, and generally considered essential), the points so determined will form an excellent ground-work for the making of a thoroughly reliable map of the property; and the labour expended in obtaining it will be well repaid, by the confidence with which the Plan may subsequently be referred to at all times; and especially should any question as to infringement of boundary, in the working of the minerals of the property, or a committal of trespass from an adjoining property, at any time arise.

As shewing the application of Traversing to a series of underground lines of a survey, we will now proceed to take the first 10 lines of the preceding example of a Field-book, in which *A* (see the plotted Plan of same), the starting point, may be supposed to represent a Pit or Level Mouth; and *B* to be the "face," and end of the 10th line. *C* may also be considered as the face of a branch part of the same workings; and if we suppose it to be required to drive from *C* to *B*, by having a point given at *C*, we shall be able by the Tables to discover the true distance from *C* to *B*, and the point to be given at *C* to drive into the "face" at *B*.

The nett results of the foregoing traversing operations is a Northing of 1878·87 links, and a Westing of 669·45 links; and if the process as before directed be performed, the terminal point of the (10) line can be exactly described from the above co-ordinates as here found and expressed.

We may now proceed from the two lines here found of the triangle, with the included right angle, to determine the other line and the two other angles, and thus complete the triangle; the rule for which is the following: Having two sides and the included angle,

RULE:—*When the angle included is a right angle, add the radius to the logarithm of the less side, and from the sum subtract the logarithm of the greater side, or add its arith.*

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complement: the remainder, or sum, will be the tangent of the angle opposed to the less side.

Then, taking the foregoing sides of the triangle, we have

Rad. + Log. of 669·45 = 12 8257181
Arith. Comp. Log. 1878·87 = 6·7261032

9·5518213 = Tan. 19° 37′ nearly.

Therefore 90° − 19° 37′ = 70° 23′ is = the third angle of the triangle.

By applying Euclid 1, Prop. 47, we shall ascertain the length of the third side: using logarithms, we have

Log. 1878·87 = 3·2738968
2
6·5477936 = 3530153·3 = 1878·87².

Log. 669·45 = 2·8257181
2
5·6514362 = 448163·2 = 669·45².

And the sum of the squares are thus = 3978316·5

Then, Log. 3978316·5 = 6·5996993

÷ by 2 = 3·2998496 = 1994·57 = √3978316·5.

= the side *opposite the right angle.*

We may prove this result by finding the number 1994·57 from the Tables: taking 19° 36′ as being the next nearest number in the minute column we have,

	Per.	Base.	Numbers.
∠ 19° 36′, and the coordinates	1878·87	669·45	
in column of thousands take	942·06	335·45	= 1000
remainder	936·81	334·00	
„ „ of 900 take	847·85	301·91	= 900
remainder	88·96	32·09	
„ „ of 900 take	84·78	30·19	= 90
remainder	4·18	1·90	
„ „ of 400 take	3·76	1·34	= 4
„ „ of 500 approximately	·42	·56	= ·5
			1994·5

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These numbers from the Tables being successively subtracted from the preceding remainder, exhaust the co-ordinates; and, adding up the successive corresponding numbers, we have 1994·5.

This last operation proves the correctness of the mode of working, and also the finding the side by Euclid I, Prop. 47; for although the last figure ·5 is not found strictly correct, yet, as the tangent of the angle lay between 19° 36′ and 19° 37′ (nearer the latter than the former), and the co-ordinates here taken out stand on the line for 19° 36′, the agreement is so near that for all practical purposes the difference may be disregarded.

It may sometimes be necessary to find the third side, and the two other angles, so that the position of the third line may be correctly laid out on the surface from one of the termini (which may perhaps be the center of a Pit or the Mouth of a Level) to the other, and the angle set out for finding the position of the other terminal point corresponding with that underground, either by chaining along the line laid out to the angle given, or by the application of trigonometry, or a combination of both: this method is much more correct than that of attempting to repeat on the surface all the lines taken underground from one terminal point to the other. Where an important work, such as the sinking of a Pit or some other matter is to be proceeded with, upon the data arrived at by such methods as these, care and precision, with the aid of good instruments, should yield perfectly satisfactory results.

It will here be proper to remark that the lesser angle, whose tangent is found by the foregoing trigonometrical computation, is not *necessarily* the "traversing" angle, by which to ascertain the length of the third side, as in this example; for "the greater side of a triangle is subtended by the greater angle," *but the traversing angle is always subtended by the co-ordinate* "Base": this will be either the greater or lesser co-ordinate according to the nature of the lines operated on In this example the co-ordinate "Base" is the lesser, and therefore subtended by the lesser angle; and as this trigonometrical operation is to find the lesser angle, it in *this case*

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finds the *traversing angle.* But supposing 1878·87 to have been the co-ordinate "Base", and 669·45 to have been the co-ordinate "Per.", then in that case 70° 23′ would have been

TRAVERSING COMPUTATION. No. 2.

No. of the line.	Quadrant where found.	Traverse Angle.	Designation of Co-ordinates.		Length in Links.	Latitude.		Departure.		Remarks.
						Northing.	Southing.	Easting.	Westing.	
		° ′								
1	1st	78·26	N.	E.	208	41·71	...	203·78	...	
2	2nd	76·42	S.	E.	78	...	17·94	75·90	...	
11	4th	56·42	N.	W.	246	135·05	...	...	205·60	
12	4th	64·50	N.	W.	332	141·18	...	...	300·48	
13	3rd	84·36	S.	W.	450	...	42·34	...	448·00	
14	3rd	74·30	S.	W.	320	...	85·51	...	308·36	
15	Par^{l}.	90·00	...	W.	248	...	...	...	248·00	
16	4th	10·51	N.	W.	675	662·93	...	...	127·06	
17	1st	7·54	N.	E.	436	431·85	...	59·92	...	
18	1st	12·15	N.	E.	94	91·86	...	19·95	...	
19	1st	7·44	N.	E.	216	214·04	...	29·07	...	
						1718·62	145·79	388·62	1637·50	
Subtract^{s}. lesser from greater						145·79			388·62	
Nett result						1572·83	and		1248·88	

COMPUTATION. No. 3.

20	1st	62·9½	N.	E.	655·3	306·04	...	579·43	...	
Add Northing						1878·87	Subt. Easting		669·45	

the angle *on whose line in the Tables* should have been sought the length of the third line; and not on that of its complement 19° 37′: this should be carefully remembered in these operations. It is perfectly true that the "line" in the Tables of an

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angle and its complement is always *the same*, but the *designation* of the two co-ordinates are in one case the *reverse* of those of the other.

The preceding traversing operation No. 1, embraces the lines of the plotted example of a survey at page 30 from *A* to *B*, lines 1 to 10; the No. 2 embraces the left-hand series of those lines from *A* to *C*, and diverges from the right-hand series at (2) 78.

On comparing the No. 2 with No. 1 computation, it will be seen that the No. 1 line is identical in both, being in fact the same line; No. 2 line of No. 2 computation is so much of the No. 2 line in the No. 1 computation as lies between the commencement of the line and the point of branching off, viz. at 78. From this point they are quite a distinct series of lines. No. 15 line goes due west, and it has therefore no pair of co-ordinates, but the *whole length* of the line is placed *in the column "Westing."*

The nett results will be found to differ from the results of No. 1 operation in having a less Northing, and a greater Westing; and a little reflection will shew that the co-ordinates of the "point or angle" to be given at *C*, to guide a drivage to *B*, will be a Northing and an Easting; consequently it will be in the first quadrant.

No. 3 computation, line 20, supplies the data to make the results of No. 2 equal to those of No. 1, arriving in fact at the same point; and a comparison will shew that the Northing in No. 1 is 306·04 more than in No. 2, and that the Westing in No. 1 is less than in No. 2 by 579·43; and we must reduce the No. 2 Westing to that extent, by having an Easting co-ordinate; therefore a Northing and an Easting: from these data we must now decide the angle and the distance, according to the method before given: viz.

Rad. + Log. 306·04 = 12·4857782
Log. 579·43 = 2·7630010
9·7227772 = Tan. ∠ 27° 50½.

Therefore the angle opposite the co-ordinate Base is

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$90^\circ - 27^\circ\ 50\frac{1}{2}' = 62^\circ\ 9\frac{1}{2}'$; and taking this ∠ and the co-ordinates as follows.

		Per.	Base.	Numbers.
		306·04	579·43	
and finding		280·22	530·54	= 600
	rem.	25·82	48·89	
„ „		23·35	44·21	= 50
	rem.	2·47	4·68	
„ „		2·33	4·42	= 5
	rem.	·14	·26	
„ „		·14	·26	= ·3

we thus find the length of line No. 20 equal to 655·3 links.

We might have arrived at the same result if we had taken the whole of the lines around from *B* to *C*, and have combined them in one computation, omitting No. 1 line and the first 78 links of No. 2; that is, taking No. 2 line as 276 links instead of 354: in that case however either the right or left-hand series of lines would have *a different designation*, accordingly as the survey was taken from *B* to *C*, or from *C* to *B*; if the former, the *right-hand* series would have opposite designations, and if the latter, the *left-hand* series would have the opposite designations. This operation may easily be performed as an example for practice.

Having gone thus fully into the working of underground traverses, and there being really no difference in the mode of application of these principles to any lines either on the surface, or otherwise, there will now be no difficulty in applying them to any series or combination of lines whatsoever to which they are applicable. It is unnecessary therefore to pursue this part of the subject any further.

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CHAPTER VIII.

AN IMPROVED DIAL AND PROTRACTOR.

For the adoption of the true meridian as the working base-line of the Survey and Plan, it is necessary to have an instrument suited to such method of working; for the practice of the process of computing it from the "declination", through all the varied angles of each successive survey, and thereby reducing the several angles to their relation to the true meridian, would be a matter of great labour, and its practical difficulty would, as a rule, prevent its adoption; and the practice of a more correct process thus requires an improved instrument for the direct taking of the angles of a survey, in relation to the true meridian as a base-line or zero.

It would be easy enough, in the matter of a simple surface survey only, to represent upon the plan the true meridian; but in the matter of mining surveys where the Plans are being constantly added to over a long series of years, and where the magnetic needle is the medium (and doubtless the best) of adjustment for the instrument, it seems to be essential, to the adoption of the true meridian as the working base-line, that the instrument itself should contain the appliances and means for the necessary correction; while, at the same time, admitting of the same simple method of reading the angles as in the ordinary make of instruments.

To provide for this we have designed an improved circumferentor, by the use of which the correction is made without in any way complicating the method or operation of working the instrument, or of reading and entering the angles of the survey. This improvement consists of an adjustable vernier, working in the divided ring of the dial-box to which the needle is set, and on which the reading verniers move; and it reads on the inside of the ring, and downwards to the bottom plate of the dial-box: and a small portion of the initial part of

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the fourth quadrant is divided on the said plate to half-degrees for this operation; and on this the vernier, which reads to minutes, is adjusted; so that its reading, reckoning from the ordinary zero or 360°, expresses the correct declination of the magnetic meridian for the time being. This adjusting vernier carries a small angle piece which works flush with the inside and top of the ring, and for which a small portion of the ring is sunk, by cutting away; and the divisions so cut away from the top of the ring are recut on the sunk part, so that the instrument may be used by the old methods when desirable or necessary: the small angle piece carries a line, in prolongation of the zero line of the adjusting vernier, on its side and top, and to this line the needle is always set instead of to the ordinary zero of the instrument.

The needle being set to this adjusting zero, the ordinary zero of the instrument will be in the *true meridian*, and all the readings of the survey will express the several angles which the successive lines make with that meridian.

If then the meridional lines laid upon the plan be those of the *true meridian*, the protractor must be laid upon those lines; and the "readings" are to be then taken, or marked off, just in the same manner as though the magnetic meridian was being worked from—there being in this respect no difference in the process; and all computations are thus rendered unnecessary.

It will be necessary to adjust this "declination" or adjusting vernier, either quarterly, half-yearly, or yearly, according to the necessities of each surveyor; but in general it would be sufficient to make the adjustment half-yearly. And the plan should have the dates of the general surveys, and a record of the amount of the declination to which the instrument is successively set, entered in tabular order regularly, so that at any future time the later surveys may be made precisely to accord and compare with those made at former periods.

The adjustment is easily effected by the use of a small key, by which the vernier can be moved either way at pleasure; but it is not liable to get out of order, and will not move except when acted on by the accompanying key.

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For the purpose of applying this principle to surveying it is necessary to have the means at hand to correct the instrument periodically to the true meridian. This may entail some little labour and expense at the first, but surely the desirability of having first-class Plans will far outweigh any such consideration. Only those who have been much engaged in mining operations, and have observed the great expense very often attendant on bad surveying and bad Plans, as well as the frequent loss of no inconsiderable quantity of valuable mineral, will for a moment question the desirability of adopting good and correct methods of surveying,—unless indeed such persons are blinded by prejudice against the introduction of improvements, in this, as well as in other matters connected with mining.

The expense of procuring the improved instrument, or of having the improvement applied to an existing instrument, is indeed inconsiderable. For the application of the principle continuously upon any property it is desirable—though not *absolutely* necessary—to have two distinct points of observation, either *corresponding with* the true meridian, or making a *known* angle with it. This having been procured it only remains to take the instrument periodically to one of these points, and observe with the adjusted telescope the pole or other object at the other point: if they are *in* the true meridian, set the zero and telescope of the instrument to the said pole, or, if they make a *known* angle with the true meridian, set the verniers of the instrument to the said required angle, and turn the entire instrument round towards the pole or object until the telescope accords with it, while the verniers read the permanent variation of those points from the true meridian. Then observe if the needle and the adjusting vernier agree with each other; if they do not, take the key of the adjusting vernier and move it until it accords with the needle exactly, and the readjustment is complete. Care must be observed in performing this last operation to guard against any attraction of the needle from any cause, or with the correction of one error another will be committed; proper diligence will however ensure against this.

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Now it is not absolutely necessary that the true meridian should be laid out upon the property, in order to practise this improved method of surveying, for we may take *any* line near the true meridian (so that it is distinctly understood), and adjust from that line periodically, in the same way as before mentioned, and so ensure the advantages derivable from a correction for magnetic variation: it is doubtless however preferable to have the line laid out either *in* or *from* the true meridian, so as to apply the principle more completely.

We give subjoined two methods for finding the true meridian at any place whose latitude and longitude are known, or are determined.

1st. By equal altitudes of the sun, or a fixed star.

The theodolite being fixed in a position selected as one of the points in the desired line, measure the horizontal angle from the said line to the sun or fixed star (whichever is used), when it is not near the highest or lowest point of its apparent daily course, and take also the altitude, adjusting the intersection of the hairs of the telescope to it, in some marked and definite manner. Leave the limb clamped and let the instrument remain quite undisturbed until the sun or star is approaching the same altitude at the other side of its apparent circular course. Then, without moving the body of the instrument, unclamp the limb, and direct again the telescope towards the same object, and follow it with the aid of the tangent screw until the cross hairs correspond precisely as before with the same relative position upon the disc of the object, as in the first observation: this being done, read off the horizontal measure of the angle between the assumed line and the new direction of the observed object; the mean between the two horizontal angles will define the position of the true meridian, *if a star has been observed.*

If the *sun* has been observed a correction is required in consequence of the sun's change of declination. When that declination changes towards the north the approximate direction of the meridian as found by the foregoing method is too far to the right; if declination changes towards the south it is too far to the left.

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The required correction is found by the following formula:—
$\frac{\text{change of sun's declination}}{2} \times \text{sec. latitude} \times \text{cosec.} \frac{1}{2}$ angular motion of the sun between the observations.

Example. Given:—Date of observation (say 26 July); sun's declination changing towards the south at the rate of 13′ per day, or 32″·5 per hour; time between the observations, say 6 hours, change of declination for 6 hours 3′ 15″; angular motion of the sun between the observations, say 80°; latitude of place of observation, say 51° 34′ N.

Then the correction becomes

$$\text{Log. } \frac{3'\,15''}{2} = 97''{\cdot}5 = 1{\cdot}9890046$$
$$\text{,, sec. } \angle 51^{\circ}34' = 10{\cdot}2064865$$
$$\text{,, cosec } \angle 40^{\circ} = 10{\cdot}1919325$$
$$\text{,, } 244'' = 2{\cdot}3874236$$

therefore the approximate direction as found by the observation is too far to the *left* by 244″, or 4′ 4″,

In the preceding process it must be observed that the mean of the two horizontal angles is their half-sum when they are at the same side of the station line, but their half-difference when they are at opposite sides of the said line.

2ndly. Where Greenwich mean time is given or obtainable, by the aid of the telegraph, procure the exact Greenwich time on some convenient day, and with the "equation of time" change that mean time into true apparent solar time: then take the longitude of the place of observation, and add for each degree of difference in west longitude 4 minutes of time, and for each minute of longitude 4 seconds of time; if the observation is in longitude east of Greenwich the same has to be subtracted instead of added.

Then these differences for longitude having been added to, or subtracted from the Greenwich apparent solar time, gives the apparent solar time at the place of observation, and at 12 of that time the sun is due south.

A chromatic object-glass for the telescope is necessary in making these observations.

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The small round legs of the mining dial or circumferentor are not sufficiently strong for out-door work in windy weather, when the telescope is being used; for the action of a slight wind will often be sufficient to cause the needle to be unsteady. There seems to be no practicable remedy for this but to have a strong tripod-stand for use in out-door surveying; and while this entails the expense of two sets of legs for the instrument, the advantage gained is often much more than sufficient to compensate for the extra cost. The tripod-stand cannot be used with advantage underground, in many places, for it is too heavy and unsuitable; while it is by far the best stand for surface operations.

Improved Protractor.

We have also designed an Improved Protractor, in the using of which the successive lines of the survey are run off at once from the instrument to their positions upon the Plan, instead of making punctures in the paper, with pencil marks and numbers to distinguish one angle from the other; the pricking of the paper is also thus avoided.

The instrument is made by lengthening out the central bar that carries the verniers, to about 3 inches each way beyond the outer side of the divided circle, and at each end of this bar there is a transverse bar: and on the ends of these transverse bars and reaching from one to the other, are fixed two ebony or metal bars—one on each side—sufficiently distant apart for the inner edge to just work clear of the divided circle. The ends of the central bar each carry a small glass with a + cut, so that those two and the central + are in exact alignment, and form the zero of the instrument. Each side of the frame is exactly parallel with this zero line.

The outer side of the divided circle has a projecting shoulder cut on it, and is provided with a clamp, and adjusting tangent screw, as in the Theodolite.

In plotting a survey from this Protractor it is first laid

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upon the meridional line in the most convenient position, and each line of the survey is then laid down in succession as taken from the instrument, either with the large set-square, or parallel ruler, and at once laid down in its proper position; and thus the work of first marking off and numbering the readings is rendered unnecessary.

With the large set-squares either one side or the other of this frame will be sure to be convenient for plotting from.

These instruments can be procured from Messrs Troughton and Simms the eminent Opticians, who have made them from the designs of the author.

CHAPTER IX.

PLOTTING THE SURVEY, ETC.

If the directions respecting the proper seasoning of the paper, laying down the meridional and transverse lines, &c., have been complied with, and the survey made and duly entered in the field-book, the plotting operation will now be proceeded with.

Unless the position of the boundary, and other objects on the surface, can be so far imagined that the site of the pit, or level, can be with confidence fixed for some particular point on the paper (this can frequently be done from some old plan, where such is in existence), the surface survey should be carefully laid down first; and the position of the pit or level having been marked, the underground workings can then be taken in succession.

Taking the underground survey, and the position of the starting point being known or fixed upon, the first thing will be to fix upon an intersection of base-lines from which conveniently to take, or mark off the compass-readings correctly on the paper with the aid of the Protractor.

To produce satisfactory results the surveyor should be possessed of instruments of the best kind, and should then

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take care of them. Good instruments once possessed and taken care of will last a lifetime, and will always have the confidence of the owner; but even the best tools, if roughly and carelessly used, cannot be expected to ensure correct results; and badly made instruments can never be reasonably supposed to do so: and the surveyor may rest assured that should his plans prove to be incorrect, the faults will never be attributed to his tools, but to his own want of skill, for he will be expected, or supposed, to have correct tools to work with.

A good protractor is a very essential thing, and those with double folding arms with verniers divided to minutes (when of the best make) are, next to the improved instrument spoken of in the preceding chapter, the best; this instrument having been correctly fixed on the meridian line, the center coinciding with one of the intersections, the two readings of each line should be made to coincide with the verniers, with the aid of a magnifying glass, and both points marked on the paper with a small pencil circle around the punctures, and with the number of the line to which they refer, or run off at once to their position, as the case may be. This having been done with the whole of the lines (if with a folding arm protractor), or of as many of them as can conveniently be marked off from that part of the paper, the readings should then be taken backwards in succession as a check, to see if each pair has been correctly marked off: this being done the protractor will now be removed, and the laying down the lines proceeded with.

For running off the lines either from the improved instrument, or from their markings as before mentioned to the position they are to occupy on the Plan, the best instruments are a pair of large pear-tree angles or set-squares: these will be found to be far preferable to a parallel ruler, or even to one set-square and a straight-edge; for the large set-square has a much broader bearing on the paper than a straight-edge, and is much steadier and less liable to those small lateral movements which will frequently be found to occur with the straight-edge (unless it is a large steel edge, and then it is too

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large to be handy for this operation), when sliding in close contact the one over the other, to the position for the lines.

It will be found conducive to accuracy to mark off no more compass readings in any one place on the paper than can easily be run off to their position with one (except in occasional instances) movement of the set-squares; for it will be better to fix the protractor in a new position, and mark off the readings nearly on the part of the paper the lines are to occupy, than to mark off all in one place, and be under the necessity of running them off across a considerable breadth of paper, to their several positions; and with the meridional and transverse lines before recommended, the protractor can be put at any intersection of those lines desirable.

The first line should now be marked in its position by placing the side of the set-square to the two angle-points marked 1 (and a check upon this operation will be afforded by running the eye along the side of the set-square, and observing if it cuts the intersection of the meridional and transverse lines), then placing the other set-square to that side of the former which will the most readily permit the proper side of it *to come upon the starting point* run the line off to its position: a faint pencil mark should now be drawn along the edge of the set-square through it with a hard pencil, so cut that it shall have a thin wedge-like edge, and a flat side to slide against the set-square; and having drawn a line sufficiently long to embrace the distance to be marked off, run the set-square back again to the points to see if it still remains parallel with them; this being proved, next take the compass or dividers with the adjusting leg and the diagonal divided scale, and set the legs to the length required; or if the line be too long to be marked off at once in this manner a portion of the length may be marked off with a scale, and the remainder, including the part less than 100, taken in the compass and added to the former part; a small puncture should be made to indicate the end of the line, and it should be distinguished by a small pencil circle and numbered; also remember to put the number at the *beginning* of the line, as shewn in, and to correspond with, the field-book; the next and

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succeeding lines should then be operated on in the same way, until they are all marked off in their respective positions. In progressing forward it will frequently be found that the next line to be put on runs almost at right angles to that last plotted, and except the workings of the mine are thoroughly well known to the surveyor he will be at a loss to know whether it should be a turn to the right or left hand, if he has not remembered to indicate the turn in the field-book; and for this reason the practice should never be omitted, but by turning to the field-book the mark should at once indicate which way to draw the line, whether to the right or left hand; and so on of all the other turns that are capable of misleading without a distinct mark for guidance.

Having laid on all the lines, and being assured of the correct lengths, etc., the different objects and particulars entered to each line in succession should now be placed upon the plan, as indicated by the entries in the field-book.

When we come to a point where the survey has subsequently been continued in another direction, as for instance at 78 ② of the example of a mining survey before given, the length 78 should be marked with the compasses from the diagonal scale, and the "ribs" sketched with the pencil on the proper side, to indicate the position of the commencement of the subsequent work; but where stall roads, faults, commencement of gobs, ribs, or other things have to be indicated it will be sufficiently accurate to mark them off with a pencil, from a long scale laid upon the line in a correct position for so doing, or with a small set scale where necessary. The matter to which these lengths refer should be marked down to each line in succession (after all the lines themselves have been laid down), as the work of filling up proceeds, so that there may be no error from memory in trying to remember subsequently to what the marks refer.

In this way should all the workings of a colliery, or other mine—with the exception of stall-points—be marked down in succession; and as each page of the field-book is completed a mark should be made upon it distinctly, to show that it is done with.

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In reference to the points of stalls, it will be unnecessary to lay down these points in the same manner as those of the important headings, and other parts of the workings. The handiest way of laying down the points of stall roads is to take the small protractor which usually accompanies the other drawing instruments, and laying it properly on the meridional line most conveniently situate, and at one of the intersections, mark off the point with the pencil, and at once with the parallel ruler run off the line to its proper position, and lay down the stall to which it refers; and so on of the others in succession. This will be sufficiently accurate for these things, and they will be pricked off and laid down at once in the operation of laying down the details, instead of mixing them up with the points of the headings and other more important parts of the survey.

If the mine "pitches" too much to make the correction to reduce the measure to "horizontal" as the work of surveying proceeds, care should be observed to make the reduction before the plotting is proceeded with. Where the pitch is general, one taking of the angle of elevation or depression will mostly be sufficient; but if the pitch varies, it will be necessary to observe the angle of elevation or depression more often, and to enter each distinctly: if it is considerable it will be advisable to reduce the lengths of the whole lines, and of any intermediate particular object by the Traverse Tables, for those tables are as applicable to the reduction of hypo. to base, as to the working of traverses on the flat. But here it must be borne in mind, that the horizontal measure will *invariably* be represented by the figures as found in the column "latitude" or "perpendicular," and the other column will shew the vertical rise or fall in the length of the line: in this application of the tables they form a ready medium for correcting the different rises in mines that pitch much, and by an expeditious and correct operation to facilitate the elimination of the true horizontal measure. And where the pitch is considerable, 10° or upwards, the horizontal measure decreases rapidly, and renders it requisite to observe the more care in obtaining the angle of altitude.

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While the correct laying down of mining surveys is not difficult to those who go about it with care and diligence, and with a genuine intention to ensure accuracy, it will seldom occur that carelessness or inattention, or a despising of those small niceties which are essential to ensure precision in working, will result in anything but annoying disappointment.

The whole of the workings having been put upon the plan, together with all the details of which note has been made in the field-book, the matter of "inking in" will be ready to be proceeded with. Where two or more veins of mineral are worked one over the other, and are placed upon the same plan, it will be necessary to distinguish one from the other in the colours assigned to the several separate workings, according as fancy or taste may decide, so that each may easily be recognized, with their several connections. Some use the brush in distinguishing the veins one from the other, using black tc mark all the workings in, but painting the spaces of each between the lines with a distinguishing colour: of course, these details are very much matter of taste or opinion, and are not of such importance as those principles upon which *accuracy* depends; but we hold that, so far as possible, it is better to dispense with the brush, and use the colours only with the drawing pen; and we consider that a mining plan will generally look neater and better managed in this way than if the colours are put on with the brush, over all the exhausted space. With a surface plan which is finished at once the colouring, shading, etc. may be put on with the brush, and will if done well look well; but with mining plans which are constantly being *added to* it is different, for in this case if the shades as laid on with the brush are not precisely alike they do not look well; and if the colours selected are not simple colours the difficulty of exactly matching them is increased, therefore we think that as much as possible the brush should be dispensed with on a mining plan.

It is very easy in competent colouring hands to make inaccurate plans *look* well, and it is easy to deceive the inexperienced into saying much in praise of a plan so finished, and of the person who has finished it; but no amount of colour

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will make an *accurate* plan: and while every surveyor should seek to finish his work neatly his chief care should be to be accurate, and this can only be attained by constant attention to, and practice of, those essential principles upon which accuracy depends.

The manner of laying down the surface lines, and the details of the surface survey, does not essentially differ from that already indicated for the underground survey. In general the surface lines will be much longer and less numerous than the underground lines, and their accuracy will admit of frequent proof. If the groundwork of a survey has been formed by a series of triangles and long base lines in the way indicated in Chapter XI., the laying down the details and the filling in the shorter lines will be comparatively easy; and by a proper disposition of those lines to easily embrace the fences etc., and distinct memoranda in the field-book shewing where they abut on the main base lines, their accuracy, and the accuracy of the plotting of the main lines, will be constantly and reciprocally checked.

The finished plan will of course bear the descriptive title of the property; the name by which it is distinguished; together with the parish and county in which it is situate, and the name of the owner; also on the different boundaries the names of the owners of the adjoining properties. The scale to which it is made will be indicated, and also the detailed area of the property where necessary, and the total area. It will also bear the names of any particular farms, houses, brooks, rivers, woods, faults, or other objects contained within the property.

If the paper has been divided into 10 acre squares as before indicated these will generally assist in the computation of the area: if the whole squares are taken separately, and the parts separately, and the latter added to the former, the aggregate will be the total area. It will however be well to take also another method of computation, that of computing the property as a whole, without reference to the squares; and by comparing one result with the other a check will be obtained upon each computation, and the result obtained will

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be entitled to greater confidence. The area will of course be temporarily divided for computation into trapeziums, triangles, etc. principally, and the rules of practical geometry applied to compute the area of those and other figures necessarily entering into the division.

If the meridional lines upon the plan are those of the True Meridian there should be a columnar table on one margin of the plan, in which should be successively entered the date of the last general survey, and also the amount of "declination" to which the instrument was adjusted for the survey; this will then afford a systematic view of the correction continuously applied, for reducing the angular readings to the True Meridian.

It will be found very useful to have a sheet of good tracing paper or tracing cloth, divided into one acre squares (drawn to the same scale as the plan with which it is to be used), in black lines, and each of these squares bisected in both directions with ink of another colour in faint lines, which subdivisions will consequently be each equal $\frac{1}{4}$ acre. If it is then necessary to see approximately the area of ground exhausted of any particular vein of mineral, it will be only necessary to lay this sheet of divided paper on the exhausted space represented on the plan; and by counting the whole acres, and counting and averaging the $\frac{1}{4}$ acres (which can be done by a practised eye very nearly), and adding these together, the area will be obtained to very near the truth, without using pencil lines about or drawing figures upon the plan. And by doing this at the end of each year, and comparing the area of ground exhausted with the coal or other mineral obtained from it, it will be seen at once whether the vein is producing the quantity of mineral which under the concurrent circumstances it ought to do. The side of a square whose area is equal one acre measures 316·228 links.

As examples of the quantities we have proved different veins of coal to produce per acre, for each 1 foot of thickness of the veins, we beg to refer the reader to what is said on that subject in Chapter XII.

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CHAPTER X.

THE BUSINESS AND APPLICATION OF SURVEYING.

THE work and business of a surveyor enters largely into mining operations, and particularly into coal mining, and it may very fairly be said that the extent to which good surveying is applied in mining, goes in some degree to indicate the advance made towards a perfect system of management; for although it can never take the place of, or supply the default of, discipline and good scientific knowledge, yet the application of scientific knowledge will proceed, in no small degree, through the channel of good surveying.

Given: A mineral property to be worked, and the direction in which the measures dip being known, it will be of the first importance to know the figure of the property under consideration, so that the position for the "winning" may be determined upon, in order that it may be so situate as to facilitate the economical and convenient raising and draining of the minerals, as well as their despatch to market; and thus a correct Map will be essentially necessary, so that the plan of working may be determined upon. It is still however often the practice to allow the colliery or other mine to form itself, as it were; there being no prearranged plan of development, but simply leaving the different principal headings to follow what appears to the workmen the most natural course. This plan however generally, or rather *invariably* leads, sooner or later, to a complication of workings ill adapted to ensure either the most perfect ventilation of the mines, or the convenient and economical carriage of the minerals to the bank.

If it is a winning by means of a pit, and it is in contemplation to raise a large daily quantity, the laying out of the pit bottom will be a matter that should be well considered; for as this part of the mine will have to pass the whole daily quantity of mineral raised, economy is sometimes considerably affected by the way in which it is laid out: and the most perfect ar-

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rangement for passing the full wagons on to the carriages, as well as the empties off for entering the workings, will be found to be worth all the thought that can be bestowed upon it, so as to ensure convenience and despatch. Where the empties are conducted away by a separate road, which has just sufficient fall to keep them moving on to where they are taken off by the horses, or other hauling power, the road will require a fall of from an half-inch to an inch per yard, according to the state the trams are kept in for easy running.

Engine drawing planes on the levels, self-acting incline planes to the rise, and engine drifts to the dip, are now being more generally used than formerly, to cheapen the cost of haulage by reducing the number of horses, as well as at the same time to keep the air more pure and cool than it can be where so large a number of horses, as some collieries would otherwise require, are passing through all the workings continually; and the correct and well-considered laying out of these works and their "banks" will have a considerable effect upon the subsequent cost of working them; for if they are not (except in regular and intentional curves) practically straight, the wear and tear and consequent cost of the wire ropes are very much increased; so that it becomes a matter of great practical importance to get the engine and incline planes in perfect alignment, thereby to ensure that whenever the ropes are by the strain lifted off the rollers they shall again fall back into their correct position, to prevent chafing and cutting against the ground, and surfaces that are not rolling: and if the supervision of the opening of this work is given into the hands of the surveyor, he should take particular care that it is thoroughly done.

There is again the work of opening the headings so that they may be as near as is practicable parallel with each other, when the best point for them has been determined upon; for few things look worse on a mining plan, or prove more objectionable in the practical working of mines, than having all the headings going at random, some to the left hand and some to the right, some giving the stall roads 40 yards to go, and others giving 140 yards before they reach their end; but if they are

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driven parallel the coal can be worked much better, and more systematically, and as a natural consequence cheaper and cleaner. And while we know that it rests with the management as to whether such a system is allowed to obtain, and that it cannot well exist where there is a systematic plan of having "points" put on all the headings (and the workmen made to keep them), yet there is very frequently much less care bestowed on this matter than there should be, even with those who will at once admit the necessity and desirability of the principle.

It is sometimes the practice to have points put upon all the stalls where "long-work" is not adopted, as well as upon the headings, and in some veins there is no expenditure of labour that returns a more ample interest than does this; for it is of the first importance to keep the pillars their proper thickness while the roads are going in, to prevent their being reduced, and often as a consequence destroyed, by being "robbed" and made too weak to sustain the top—occasioned by crooked driving; and not only do the pillars thus get crushed and rendered partly, and occasionally wholly worthless, but heavy falls are often thereby occasioned, and sudden outbursts of explosive gas rendered more frequent, which would have exuded more gradually, but for the fall, and the ordinary currents of air would have been able the more effectually to dilute it, and render it less dangerous than is possible when it comes off in large quantities suddenly. Where long-work is adopted, there is not so much necessity for points on the stalls, as there is a much better chance of keeping the roads nearly parallel, when they are open one to the other along the face.

In the making of quarterly or other periodical surveys, it is of importance to have a distinct knowledge as to the position at which to begin. Where it is possible to mark each survey, by placing a *D* or any other mark determined on upon the rib or roof, there is not much difficulty in the matter; but it is not often that the positions can thus be easily determined, and then the surveyor has to fall back upon his knowledge of the relative position of some heading or stall parting, or other

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object, and trace out his last terminal position from that. Where there is not much changing of the workmen the name of the man who was working the last road in a panel of work taken, might be entered in the proper position in the book, and the chainage of this parting "cross" being taken it will generally be a good mark from which to define the position at which a former survey terminated, and from which to continue the work of surveying at a subsequent period: though this is, generally speaking, a very correct way of proceeding, yet at times there is a possibility of the surveyor being misled by having the wrong road pointed out as that for which enquiry is being made; and hence constant vigilance will be essentially necessary to ensure against error in this respect. Sometimes it is necessary to measure a level or other heading from some distinct turn, or other conspicuous object; and the system adopted, and regularity with which a surveyor is able to select these points and mark them in his book with clearness for subsequent reference, will greatly influence the time that he will be occupied in going around a large mine to take the new work opened; while an uncertainty in having positions to start from that are but ill defined in the field-book, will often lead to error by the operator taking a wrong point of departure, instead of spending the requisite time to ascertain the correct: hence nothing will contribute more to accuracy than a thoroughly clear and careful method of keeping the field-book, and of entering in a uniform manner the different matter which pertains to the survey made, and whatever may forward the work of continuing the survey at a *subsequent period.*

To facilitate the work of periodical surveys, we would strongly recommend the surveyor to adopt some particular *route* through the workings, and to keep up that route at all his surveys. Also, before going about the survey of a mine or colliery at which he has been before, to sit down and go over all the principal points of his last survey,—making notes in succession upon the different points from which he is about to continue the work of former surveys; these notes being entered in succession in a condensed form on the first page allotted for the new survey, will be all under his eye, and he will

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see them all at a glance when proceeding to the operation of surveying, instead of having to search through the whole of the entries made on the last occasion, at each different point of the work. Much time is thus saved in the underground operations, and this system has the additional advantage of bringing before the mind's eye the whole of the workings, and may perhaps recall to mind several matters of importance which it is advisable to note closely, and which, but for it, would probably have been overlooked. It also induces a correct habit in the matter of making entries in the field-book, and of so placing the particulars that they shall be uniform for extracting the notes when required on the next occasion.

The matter of moving points and setting out the gradients of drivages has been treated of in another part of this work; therefore it is unnecessary to go further into that part of the subject in this place. The learner will have no difficulty in ascertaining the point to be given to a drivage, if the line to be followed be first laid down in position on the plan, and next with the parallel ruler or other instrument it be run off to an intersection of the meridional and transverse lines; after which, placing the protractor in its proper position, see what is the angle made by the line of the proposed drivage, and making a note of the same in the field book, give that angle with the instrument, or dial, to the proper place underground.

In laying out the siding communication, and railways, to the tips or screens of an extensive colliery, or for Iron Works or other operations of large extent, there is need of great care and discernment, and few things will more effectually test the skill of the surveyor, than the designing and planning of these things—indeed it may be almost considered as an entirely distinct matter from the ability to make an ordinary survey and plan; for the latter is, more simply, the making a plan of things, as they already exist, while the former is the *designing* the means of communication for an extent of operations which demand convenience of arrangement with facilities for despatch, in all its details, and this will call for the exercise of sound engineering skill; and upon the successful manner in which these are laid out to meet the peculiarities of the traffic to be

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accommodated, and provided for, will depend the amount of engine or other power that will be required to move about, and to place the same; and it is not too much to say that a bad arrangement of roads will speedily involve the employment of an extra engine for shunting, with all its attendant expense, besides perpetuating a continuous existence of more wear and tear, upon both roads and trucks: therefore, the accomplishment of this part of the surveyor's or engineer's work will demand his best energies, for the successful accommodation of the traffic of large works.

It is of great importance to arrange the gradients, wherever it is practicable, so that the wagons shall pass under and away from the colliery screens by their own gravity, giving just sufficient fall to the road to overcome the friction of the rolling surfaces, and thus avoid the necessity of having horses always in attendance: and while in many places the natural conformation of the ground is such that this can be accomplished without the least difficulty, there are others which require to be carefully thought out, to properly accommodate the requirements of the works. And as the rails of the sidings about works are seldom very clean, consequent upon the nature of the traffic to which they are subject, it will not be advisable to count upon flatter gradients than about 1 in 100 for the wagons to run alone, and if a little more fall can be given so much the better; for while a gradient of 1 in 100 will allow for about 22·4 lb. per ton for friction, and should under good conditions be much more than sufficient, yet if wagons and roads are not kept in good running order there will not be any considerable superfluous margin.

In Iron Works it is often impossible to arrange the roads with falling gradients in either direction, to in any appreciable degree facilitate some portions of the traffic; and occasionally the nature of the traffic less requires it than at collieries; but still in such instances there is always much to be considered in the disposition of the roads and partings, to provide for that convenient despatch which is essentially necessary, where so much is being done constantly and unremittingly, night

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and day; and for which no further rule can be given than that each particular case must be considered on its own merits, always bearing in mind the quantity and kind of traffic to be provided for, together with the space at hand that can be assigned for its accommodation: and wherever an advantage is to be gained by the adoption of some particular gradient, and there are no insuperable difficulties in the way of its being carried out, such details should always have due consideration.

The practice of levelling for mining purposes does not much differ from that of taking levels for other works, further than this, that when it has to be done underground it is accomplished under very considerable disadvantages; and great care is necessary in throwing light into the telescope, so as to be able to see the cross-hairs, and to get a steady light, yet only what will be just sufficient for the purpose; and also to hold the light as much as possible in the alignment of the axis of the telescope, or else the cross-hairs will appear very unsteady, and the vision of them will frequently be flickering and uncertain to the eye. A good steady light will also be necessary for the assistant who holds the staff, so that the figures may be seen with ease and certainty. There is often great difficulty in securing anything like a good B. M. (bench mark) underground, in consequence of the movements of the ground, but the inconvenience arising from this is generally much less than in important surface works.

The business of surveying as applied to other operations than that of mining etc., has been so frequently and ably treated of before by others, that those who seek specific information on such branches may safely be referred to those works for the information they are in need of.

In the succeeding chapter will be found a more full explanation and illustration of the application of Triangulation to a considerable surface survey; and as the value of a Map depends upon its accuracy, and in mountainous districts the operation of chaining is rendered much more difficult and less accurate, by reason of the uneven nature of the ground, it seems to be most desirable that the principal groundwork of

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every important survey should be formed by the application of those principles, therein explained and applied.

CHAPTER XI.

ON TRIANGULATION, ETC.

We will now proceed to give an example of the application of Trigonometry to a surface survey, shewing how a property of a certain figure may be divided for Triangulation, and computed through the whole series of lines. This example is not from any actual survey, but is given as an instance of the application of the principles enunciated in the foregoing chapters of this work.

The superiority of these principles—if accuracy is considered to be at all desirable—cannot be for a moment doubted, and the slightly increased amount of labour, if indeed there is any increase of labour, is abundantly compensated by the increased value of a thoroughly reliable Plan on which to lay out the workings, and guide them for the proper exhaustion of the minerals throughout the property to the boundaries, and the reservation of proper barriers to ensure against flooding and other mischiefs.

In the example here given, Plate 3, line *a* of No. 1 triangle is that supposed to be measured very accurately, for computing the whole of the lines of the Triangulation; and this line, called the "Base of computation," is here represented to be 2564 links. The process of computation is carried on, first from line *a* to line *j*, embracing *b*, *c*, *d*, *e*, *f*, *g*, *h*, and *i*; then from line *a* to line *k*, embracing *q*, *p*, *o*, *e*, *n*, *m*, *l*, *i*, and *k*; thus the lines *e*, and *i*, come into each of the series of computations, and will each form a check upon both series, one of the other; and if these lines come the same in each (as they ought to do) it is so far satisfactory to the operator. Then, selecting one of the lines—say, for instance, *k*— as a "Base of verifica-

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tion," it should be measured on the ground with the chain, and checked with extreme care, to ascertain if it corresponds with the computed length: if it comes within ·5, or 1 link of the computed length, it may be looked upon as being very satisfactory.

Care should be taken to avoid as much as possible the adoption of angles greater than 90°, as they are neither so convenient, nor so easy of computation: it should be also carefully observed that the sum of the angles of each triangle equals 180°; and that the sum of all the central angles of each closed polygon (at *A* and *B* for instance) equals 360°.

An instrument, theodolite or circumferentor, of the best make, and in perfect adjustment, will be requisite for taking these angles; and having carefully levelled the instrument the surveyor should proceed to take the angles, and enter them in a sketch, made for the purpose, of the several triangles in their proper relative positions. In some states of the weather the refraction of light will have a very perceptible influence upon the operation of taking the angles, and this should be carefully noted, and errors as far as is possible guarded against: for instance, if there are passing clouds, and *one* observation (or one of the readings for determining the angle) be taken while the sun is obscured and the other *after* the cloud has passed, there will often be a perceptible difference (dependent upon the state of the atmosphere) in the measure of that angle, compared with the measurement when both observations have been taken either in sunshine or in shade. Therefore it is well and proper to bear this in mind, and to check the readings of each angle by a double operation, before the instrument is removed from the position or station.

At *A*, and *B*, the whole of the angles at the center of each polygon can be taken and checked at one fixing of the instrument.

The trigonometrical Rule by which these computations are made, is that given before:—viz. *Add the logarithm of the given side to the sine of the angle opposite to the side required, and from the sum subtract the sine of the angle opposite to the given side; the remainder will be the logarithm*

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of the side required: or, instead of subtracting the sine of the angle opposite to the given side add its co-secant, and the sum will be the logarithm of the side required.

Then, the given side a being 2564 links, we have the following computations.

To find side b.

As sine of $\angle 82^0\ 33'$	$= 9{\cdot}9963183$
: log. side $a = 2564$	$= 3{\cdot}4089180$
:: sine of $\angle 40^0\ 30'$	$= 9{\cdot}8125444$
	$13{\cdot}2214624$
: log. side $b = 1679{\cdot}4$	$= 3{\cdot}2251441$

To find side c.

As sine of $\angle 46^0\ 21'$	$= 9{\cdot}8594804$
: log. side $b = 1679{\cdot}4$	$= 3{\cdot}2251441$
:: sine of $\angle 75^0\ 34'$	$= 9{\cdot}9860720$
	$13{\cdot}2112161$
: log. side $c = 2247{\cdot}7$	$= 3{\cdot}3517357$

To find side d.

As sine of $\angle 75^0\ 34'$	$= 9{\cdot}9860720$
: log. side $c = 2247{\cdot}7$	$= 3{\cdot}3517357$
:: sine of $\angle 58^0\ 5'$	$= 9{\cdot}9288145$
	$13{\cdot}2805502$
: log. side $d = 1970{\cdot}1$	$= 3{\cdot}2944782$

To find side e.

As sine of $\angle 38^0\ 21'$	$= 9{\cdot}7927163$
: log. side $d = 1970{\cdot}1$	$= 3{\cdot}2944782$
:: sine of $\angle 76^0\ 29'$	$= 9{\cdot}9878012$
	$13{\cdot}2822794$
: log. side $e = 3087{\cdot}2$	$= 3{\cdot}4895631$

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To find side *f*.

As sine of ∠ 38° 21′	= 9·7927163
: log. side *d* = 1970·1	= 3·2944782
:: sine of ∠ 65° 10′	= 9·9578626
	13·2523408
: log. side *f* = 2881·5	= 3·4596245

To find side *g*.

As sine of ∠ 51° 41′	= 9·8946461
: log. side *f* = 2881·5	= 3·4596245
:: sine of ∠ 68° 35′	= 9·9689262
	13·4285507
: log. side *g* = 3419·	= 3·5339046

To find side *h*.

As sine of ∠ 68° 35′	= 9·9689262
: log. side *g* = 3419·	= 3·5339046
:: sine of ∠ 59° 44′	= 9·9363574
	13·4702620
: log. side *h* = 3172·	= 3·5013358

To find side *i*.

As sine of ∠ 48° 7′	= 9·8718681
: log. side *h* = 3172·	= 3·5013358
:: sine of ∠ 75° 9′	= 9·9852468
	13·4865826
: log. side *i* = 4118·2	= 3·6147145

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To find side *j*.

As sine of ∠ 75° 9′	= 9·9852468
: log. side $i = 4118{\cdot}2$	= 3·6147145
:: sine of ∠ 56° 44′	= 9·9222721
	13·5369866
: log. side $j = 3562{\cdot}4$	= 3·5517398

To find side *q*.

As sine of ∠ 40° 30′	= 9·8125444
: log. side $b = 1679{\cdot}4$	= 3·2251441
:: sine of ∠ 56° 57′	= 9·9233450
	13·1484891
: log. side $q = 2167{\cdot}4$	= 3·3359447

To find side *p*.

As sine of ∠ 46° 6′	= 9·8576648
: log. side $q = 2167{\cdot}4$	= 3·3359447
:: sine of ∠ 75° 20′	= 9·9856129
	13·3215576
: log. side $p = 2910$	= 3·4638928

To find side *o*.

As sine of ∠ 75° 20′	= 9·9856129
: log. side $p = 2910$	= 3·4638928
:: sine of ∠ 58° 34′	= 9·9310750
	13·3949678
: log. side $o = 2566{\cdot}6$	= 3·4093549

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To find side *n*.

As sine of ∠ 68° 8′	= 9·9675728
: log. side *e* = 3087·2	= 3·4895723
:: sine of ∠ 61° 23′	= 9·9434172
	13·4329895
: log. side *n* = 2920·2	= 3·4654167

To find side *m*.

As sine of ∠ 46° 7′	= 9·8577863
: log. side *n* = 2920·2	= 3·4654167
:: sine of ∠ 86° 15′	= 9·9990691
	13·4644858
: log. side *m* = 4042·9	= 3·6066995

To find side *l*.

As sine of ∠ 86° 15′	= 9·9990691
: log. side *m* = 4042·9	= 3·6066995
:: sine of ∠ 47° 38′	= 9·8685548
	13·4752543
: log. side *l* = 2993·5	= 3·4761852

To find side *k*.

As sine of ∠ 44° 46′	= 9·8477091
: log. side *l* = 2993·5	= 3·4761852
:: sine of ∠ 59° 36′	= 9·9357660
	13·4119512
: log. side *k* = 3666·4	= 3·5642421

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To find side *i* by this series.

As sine of ∠ 44° 46′	= 9·8477091
: log. side *k* = 2993·5	= 3·4761852
:: sine of ∠ 75° 38′	= 9·9862017
	13·4623869
: log. side *i* = 4118	= 3·6146778

being ·2 difference between the first and second computation to find the side *i;* this is satisfactory.

If it should be required to ascertain what the respective outer angles of No. 9 triangle *should* be, so as to close the polygon composed of triangles 3, 4, 5, 9, 8, and 7, and the length of the line *k* between the two abutting triangles 5 and 8, we must then apply the following rule. Having two sides and the angle between them; to find the two other angles and the third side. Rule:—

If the angle included be oblique, add the logarithm of the difference of the given sides to the tangent of half the sum of the unknown angles, and from the sum subtract the logarithm of the sum of the given sides, or add its complement; the remainder or sum will be the tangent of half their difference.

Applying this rule, we have the two given sides = 4118·3 and 2993·5; and 2993·5 + 4118·3 = 7111·8 = the sum; and 2993·5 − 4118·3 = 1124·8 = their difference.

Also sum of unknown angles = 180° − 59° 36′ = 120° 24′; and 120° 24′ ÷ 2 = 60° 12′ = the half sum.

Then, Log. diff. 1124·8 =	3·0510367
Log. Tangent 60° 12′ =	10·2420687
	13·2931054
Sub. Log. sum = 7111·8 =	3·8519795
Log. Tangent 15° 26′ =	9·4411259.

Therefore the angles will be, 1st, 60° 12′ + 15° 26′ = 75°.

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38′; and, 2nd, $60^0\ 12' - 15^0\ 26' = 44\ 46'$; and the side k will then be computed by the rule given for the other sides.

The diagram of lines of which the foregoing is the computation forms a complete foundation or groundwork on which to proceed to fill up all the details of the estate to which it may refer. Good firm stakes, or some other reliable marks, should clearly distinguish the positions of all the stations, and then poles can be set up for measuring those lines or combining short diverging lines with them, as circumstances may require, in order to take in all the requisite boundaries, fences, brooks, houses, or other matter; and, if found necessary, portions only of some of the lines can be measured from one or other of the ends if complete information for plotting can thus be obtained, and so that the correct particulars are entered in the field-book. In this way awkward and rugged parts of lines, which, with another system, would have to be measured entire to complete the information requisite to plot the work, may be occasionally omitted, without in any manner impairing the accuracy of the Plan: and no error could be continued beyond the triangle in which it arises, and could scarcely arise (with ordinary diligence) without being detected.

The selection of the secondary lines for filling up, and their directions, depend entirely upon the judgment of the surveyor being brought to bear upon the peculiarities and requirements of each particular case, and for which scarcely any two instances will be found requiring the same treatment and division: therefore the better and quicker the judgment exercised in their selection, the more accurate and less laboriously attained will be the result.

The application of these principles is often of great importance also in foreign countries, in the procuring information respecting, and the development of, their mineral resources, and for acquiring a fairly accurate idea of the stratification, correct average line of dip, direction of principal faults, and other information so necessary to guard against error in taking up concessions, and developing the mineral riches of comparatively unknown countries. For while in England,

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generally speaking, the boundaries of our deposits of coal &c., are pretty well known, in new and undeveloped countries such information has to be gathered.

The object then to be attained, is to procure the data from which to lay down a connected relative view of different and distant points; for while, often, a consideration of the peculiarities and evidences of any one small district, taken alone, will be found to contribute but little to a general knowledge of the surrounding country, and will often indeed be found, when read *by themselves*, to be completely contradictory of the *general* evidences found elsewhere, they will—when read in the light of the *combined* information to be gathered throughout the area under enquiry, and combined also with a consideration of the relative positions of those places, the character, pitch, and strike of the strata as a whole, line of faults, evidences afforded by denudations of the strata, either in large valleys or deep ravines, together with the fossils to be found in the area being examined—enable the intelligent enquirer to form a tolerably accurate idea as to the capabilities of the district under consideration to yield any of those minerals which have been so much a source of wealth and greatness to the countries possessed of them, and of which he may be in search.

In getting up a Plan of such a district as is here supposed, the application of the science of Trigonometry is generally the only practicable mode of doing so; and at the same time it provides a groundwork for the filling in any details in reference to any particular part deemed desirable, either at that or at any subsequent period.

The rules here given are those most generally employed, in such computations as are here indicated; but there are others which have to be adopted occasionally, under peculiar circumstances, instead of these, and which will be found given in treatises on Trigonometry. Also, when the lines under consideration are so large that the curvature of the earth has an appreciable effect upon them, Spherical Trigonometry must be employed, intead of Plane Trigonometry.

While the peculiar evidences of *large* districts must thus

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be sought, if coal, stratified deposits of iron ore, and some other minerals, are being sought after, there are some deposits, and amongst them the *casual* deposits of iron ore, which do not become influenced so much by the general features of large districts, but their evidences are rather to be sought for in a more confined area. Occasionally an unpromising looking outcrop will be found to lead to a very valuable deposit of rich iron ore beneath; while a very considerable area on the slope of a hill may be reddened by the descent of the rain-waters, whose solvent action upon a *slightly* disseminated sprinkling of ore in the strata of the brow of the hill will have brought about a gradual change of colour, and which may lead some persons to fancy that a very valuable deposit of rich iron ore is near at hand. Springs of water holding iron in solution will often give a colour to the surface over which it flows, and which, if taken as indicative of what may be found in the immediate substrata, will be eminently calculated to mislead. We have taken crusts of brown oxyd of iron, upwards of two inches thick, from the face of a bank over which has flowed a stream of water that has contained iron in solution, and which iron was, most probably, originally taken up from decomposing iron pyrites in the strata through which the water had flowed, as that mineral was known to exist near in considerable quantities: and this crust could not have been, from the peculiar nature of the position, many years in forming. Sometimes the material of which houses are constructed (if stone has been employed) will give a clue to deposits in the neighbourhood, by the occasional appearance of a stray lump of ore amongst the building material, especially where, as in primitive countries, the people gather and use the loose material they find lying in their fields, rather than raise it in a quarry. Sometimes the outcrop of a deposit of mineral may be discovered in going along over a country after a very heavy rain, such as falls in southern countries, which has washed the surface of all the loose débris, and left the native strata quite clean and bare—it being, in fact, nature's performance of that operation of "scouring," which is still carried out artificially, occasionally, in many countries, to discover the outcrops of metallic deposits

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and other minerals of value. Deep ravines, and the beds of brooks when dry, will also often yield unerring evidence of the presence, or otherwise, of certain metalliferous deposits; as will also the examination of the localities of disruptions, and dislocations of the strata, and also by following the line of contact of rocks which lie unconformably one upon another.

In examining any new country and seeking therein evidence of mineral deposits, these, and many other such-like circumstances, will be made use of by the experienced observer, in endeavouring to ascertain the prospects of success (setting aside for the moment the questions of labour, transit, climate, &c.) of any mining enterprise with which he may be connected and have an interest in establishing upon a profitable basis, and with which the business of surveying must become more or less intimately connected.

CHAPTER XII.

ON THE VALUATION OF MINING PROPERTIES.

As the raising of minerals, and converting them to profitable use, is one of the businesses of life, and not one of its luxuries, except perhaps to an exceptional few, whose luxuries in it consist less of profits derived from the legitimate working of mineral properties than of profits made out of the unwary, by letting them into worthless things at a very high figure under specious colours, and from which no profit perhaps ever has been, nor is ever likely to be made—those who place their capital in mining enterprises do so in the legitimate hope and expectation of reaping a proper return for its employment. There are things in which money is embarked or spent, and in which, if the expectation of profit is not very great, the liability to risk and accident and loss is at least very small; but mining is much too serious a matter to embark in simply

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from a love of the adventurous, and therefore those who take, or buy mining property, to work it legitimately, and who place their capital in it, have a right to look for an ample return upon their investment.

Whether the question of the manner of deposition of our splendid deposits of minerals, and especially of coal, will ever be decided to the satisfaction of every enquiring mind is extremely doubtful; nor does the value of the possession depend upon the decision of any such abstract question. The fact of its value is unquestioned, and those countries which possess it in greatest abundance, and also the means for its development, are found, taken at large, to be the most advanced in wealth, and prosperity, and high civilization. It is true that we do not always find an advanced state of civilization amongst the workers in our collieries and mines. The miners are a race of men whom some may judge to be somewhat repulsive and uncivilized, simply from the black appearance the coal-dust, or the red skin that the hematite mine and other accompaniments of mining, give them—adhering to the strong and able frame in consequence of the streams of perspiration that pour out through all the pores of the whole body in the laborious work of mining. Such a judgment would however be very inaccurate, and would, as a rule, convey a most uncharitable idea of the miner. That he is impulsive, and often careless of his own life and that of his fellows, we have frequent evidence of in the melancholy testimony borne to the causes which lead, or have led, to the too frequent recurrence of the sad loss of life in collieries and other mines: but it is by no means just to lay all the blame upon the miner when an accident happens, and come at once to the conclusion that it has necessarily originated in his carelessness or foolishness. Other causes, over which he has no control, and for which he is in no way responsible, but by which he is placed in imminent peril, are often operating to accelerate and bring about destruction to life and property; and some of these it is within the range of possibility to prevent, and some are events which it is to be feared no ordinary forethought could have fully averted.

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Placed thus in the midst of daily danger, and labouring in the monotonous toil of the mine, it is not to be wondered at if the miner is sometimes found to be heedless and callous; but such is not the case universally, for there will be found amongst miners men of noble impulse and generosity, and some who take a greater notice of the mineral they raise than that merely involved in the raising and filling it into the trams. There are those who are fond of collecting specimens of some of those beautiful fern fronds, and other fossiliferous impressions so frequently to be found in some strata in and about the minerals, which evince an enquiring and teachable mind; and they have also (some of them) formed some opinions of their own respecting the manner of deposition of the veins, &c. they labour in. These, and similar evidences, tend to shew that if the miner is not so highly civilized as he should be, the fault is frequently less his own than of the concurrent surrounding circumstances of his position, and perhaps also of those who are by their opportunities and education placed by Providence in a position that enables them, if they would, to assist in the work of improving his mental condition.

The many works of practical benevolence and love which the miner is found assisting in, and in some instances to initiate, shew that he has a heart as warm and generous as others more generally recognized; and if his heart is warmly appealed to in the matters of religion, purity, prudence, and charity, it will not infrequently be as warmly responded to. Therefore we would submit that if the miner is not in all things what it would be desirable to have him to be, he is not at the same time what he is capable of being made; and those with superior endowments and positions may at all times do much towards raising him to that standard, to which it is very frequently said the "safe" miner should conform.

It is occasionally said that as men grow in intelligence they dislike the mine, and that the possession of one is inconsistent with the performance of labour in the other: but to apply such judgment as a principle, simply because isolated instances may have arisen in confirmation of such an idea, would be manifestly unfair. And can it be for a moment supposed that

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an All-wise Providence has so placed these great blessings and comforts—as our mineral riches are admitted to be—in a position from which they can be brought only by the prevalence of the most ignorant and degraded class of labour? and that its removal can only be properly secured by the existence of that state of being which is utterly repugnant to, and inconsistent with, those higher attainments of our nature to which, in other works of the same All-wise Providence, we are constantly called? Surely this cannot be, and we should be guilty of great indiscretion if we were to suppose that it is not possible to secure these great blessings, and accessions to our comforts, at a less cost than the perpetual existence of a maxima of vice and irreligion.

Doubtless there will always be enough, and too much, of these in our world while the present course of things continues; but at the same time there is no reason why a general advancement in intelligence should not be striven after, for the benefit of each generation as it arises; for the more men grow in intelligence, the less will they become a prey to designing and professional agitators, and the more will the connection between labour and capital be improved. Men will see that it is to the advantage of themselves and of their employers that their labour should be performed with the greatest care, and to secure the best results; and that if capital cannot be equally well remunerated in mining enterprises with labour, it will not continue to be so employed, but will seek new fields of enterprise for its employment.

Thus we submit that this question of the state of intelligence of the labour employed has no slight influence upon the value of mineral properties; for it is well known that where there are steady, and contentedly settled men, with which to carry on mining operations, there is a great advantage in comparison of that where men are unsettled and roving, and consequently less easily controlled and disciplined, and less amenable to reason.

When mining property comes into the market for sale, its real value is a matter not always easily determined. Foreign enterprises are occasionally offered to speculators and capi-

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talists, and often consist of concessions held from foreign governments; these concessions we have known in some instances to have been both numerous, and widely dispersed; and instead of a large number of concessions being a source of strength to foreign mining it is much more frequently its weakness, for it is mostly made compulsory upon the holders that a certain amount of work shall be performed at each concession yearly, or the right to hold is endangered, and may be forfeited: and thus are many companies led into attempting too great a series of operations at the first, which, in new countries, and with untrained labour, often involve so heavy an expenditure that not a few collapse under the burden; while if attention had been confined to some two of the most promising and conveniently situate until they were fairly developed and made productive, much less preliminary cost would have been incurred, much capital saved, and the other concessions could then be gradually attended to and developed in a manner most conducive to the permanent success of the entire undertaking; and much fewer companies would then be brought to ruin.

If mining properties in foreign countries are much scattered there is much attendant expense in opening up and maintaining roads, or channels of communication and transit for the minerals; for, most likely, there will often be but few native roads that can be made available in any but detached parts; and where this is so, and native labour is used, though it may be available in sufficient abundance it may still be unacquainted with the class of work to be performed, and thus, while the labour is nominally cheap, it may in reality be very much dearer than a higher paid class of labour in other countries; and, as a consequence, the results of carrying on work in foreign countries seldom realize the expectations raised on the basis of cheap labour. These things will be elements in the calculation, in seeking to form an estimate of the value of foreign mining or other properties for the profitable employment of capital, and great care will be needful in making such valuations: for while doubtless there are many rich properties awaiting the application of capital, to yield a

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most remunerative return, there are others from which little can be properly expected.

The same may be said of properties in our own country, coming into the market; for while there are some properties which are thoroughly legitimate and sound, and offer a good security for the investment of capital, there are some occasionally offered which, if they ever have paid a return on capital, have now pretty well ceased to have any prospects of doing so any more; in fact the owners may wish to sell them in consequence of their being of no value to hold. It is, however, certain, that such transactions are not confined to mining, for in many other ways we find the same principle acted on; and if a person with his eyes open buys a worthless thing he has himself principally to blame, if he did not take due precaution to ascertain by the best available means whether it was of the value represented to him.

While coal veins, and other stratified deposits, admit of the application of general estimates of acreage yields of unworked ground, and with the cost at which the mineral can be produced and sold supply general information for computation, casual deposits cannot often have such principles wholly applied to them; for they are in some cases very variable in their features, and so irregular in the quantities yielded by similar areas, that it is but the merest guess-work to assign any quantity as a probable yield.

Doubtless, in some of the hematite iron ore deposits, the further we follow them down the greater we may find their bulk to be, and probably their richness also; but the manner of working imposed by the nature of the deposit, and the precautions necessary to ensure against flooding, will be certain, in these deposits, to affect their value in the course of time; and what will be a good system for one deposit in one country, may in another country, and with precisely similar surroundings of stratification etc., be quite inapplicable: for if we suppose the case of a hematite deposit, very rich in itself, but situate where the Lancashire practice of working downward would be inapplicable in consequence of semi-tropical or violent rains prevailing at times—an instance of which we

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have known, and have been connected with, and directing, in Portugal—some other mode of working must be adopted, so as to keep the surface intact; for were it in such cases to be broken by the subsidence brought about by working downward from the surface, the immense rains which in a very short time occasionally convert the surface of the ground into one wide sheet of water, would then quickly bring about the destruction of the mine, not alone by flooding the lower workings, but by carrying down into the workings such great quantities of the small refuse and sand overlying the district, that it would become a matter of *reopening* the mine to get at the former workings again. Of course, when the deposit being worked is situate on a hill, where good natural drainage can be arranged, such inconvenience from this cause does not arise, or is easily provided for. Under the circumstances we have mentioned, the only feasible plan seems to be that of going sufficiently deep to commence operations, and then to work upwards towards the surface, filling in the excavated space with rough material sent down into the mine; and always leaving a sufficient thickness untouched, to ensure an unbroken crust to keep out the flood waters.

These and similar circumstances will all go to tell upon the value of mineral undertakings, of the different kinds to which they respectively apply; so that the correct estimation of the value of a mineral property is often a complicated question, involving several matters which require special consideration,—and can only be duly arrived at by the examination of each property, not only upon general principles, but also with regard to the special features of the nature of the deposit; country in which situate; facilities for transit; abundance of labour; cost of establishing, developing, and conducting the operations; market for produce at a profitable price; and other matters of a relative nature which will suggest themselves to a competent valuer, who may have to entertain the question of the valuation of such properties.

We have found that veins of coal of thicknesses varying from 2 ft. 6 in. to 5 ft. have yielded the following different numbers of tons per foot of thickness per acre: viz. 1100,

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1090, 920, 1300, and 1000 tons, statute weight—taking the exhausted ground as measurement; and these numbers will probably be found to be about what it is possible to realize in practice generally, though some of the quantities may be considered to be very low; but several causes go to influence the total quantity to be obtained from any particular vein,—not only the varying specific gravity of coals, but the strength or firmness of the veins, the nature of the superincumbent strata, mode of working, and also, in no slight degree, the system of management.

As being amongst the prominent questions that would have to be entertained and considered, in valuing any colliery that may be offered for sale, are some or most of the following.

1st. The area and compactness of the property, provisions and clauses of lease:—are they reasonably favourable to the Lessee, and what is the royalty reserved, dead rent, average clause, power of assignment, of removal of plant at expiration or other determination of lease etc. etc. etc.?

2nd. What is its relative position in regard to other properties being worked?

3rd. What is its relative position for market purposes for produce; to what markets can its produce be sent; and has it good railway, or other sufficient service?

4th. What are the general known features of the strata in respect of Faults, Springs, Swamps, old Workings (if any) etc., and how situate?

5th. Are any of the veins of mineral—coal or iron—in the same property, that can be worked to the detriment of that whose value is sought, demised to *other* lessees?

6th. Quantity and quality of coal unworked, and its accessibility from Pit, or Level; and will the coal last out the term of the lease, and cover the dead rent to the end?

7th. What is the price at which the coal can be delivered at "bank" in ordinary times, all working charges paid; and what are the royalties, wayleaves, and other charges binding on same?

8th. What profit per ton will this cost admit of in ordinary

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states of the market; and what quantity is the colliery capable of producing per diem?

9th. Does the vein of coal give off much explosive gas; is the "top" good; and does it require much timber?

10th. Is there a good sound system of ventilation in operation, with sufficient air, and shafts etc. for same?

11th. How many years will the royalty last to *give profit?*

12th. Is the colliery well provided with machinery, plant etc., requisite for raising and despatching the coal; and are good plans of all the *old* workings obtainable?

13th. Are the boundaries infringed upon at any point; and do any liabilities attach to the property other than those usual and ordinary?

14th. What facilities of access to other veins, or royalties, does the possession of the present field and vein, or veins, give; and what is their money value to an incoming tenant or purchaser?

15th. What convenience, and area of spoil ground, is there for tipping rubbish etc. from the colliery?

16th. Do the minerals underlie any town, village, reservoir or accumulation of water, or any other notable place or thing, which would render the working of the coal liable to, or for, any damages, or actions at law, more than ordinary?

17th. Then:—Under all the circumstances what net profit per annum will the colliery produce, and for how many years, at a certain estimated output per annum?

An amount should be allowed off the profit for an insurance or compensation fund (in case of accident), and the income should provide a sufficient amount, after that deduction, to give a good interest on capital laid out, as well as to provide for the recouping of capital, before the colliery becomes exhausted.

The annual value etc. having been thus obtained, and any other matter observed necessary being duly considered, the present value will have to be worked out by the ordinary rules for money computations of this nature, and the result shewn in a proper tabulated form.

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We will conclude by giving a few examples of the valuation of the freehold interest in mineral property; and also of a reserved rent-charge: and these will also, to a considerable extent, illustrate the principle to be followed in estimating the value of a terminable income, annuity, or other interest, arising from a colliery, or other property generally.

Reserved Rent Charge.

EXAMPLE 1.

A person is entitled to an annual rent-charge of £140 upon a property, for a remaining term of 17 years; and it is required to clear the property of this charge:—the proprietor is willing to accept an immediate equivalent, and to allow interest at the rate of 3½ per cent. per annum. To what amount does he become immediately entitled?

To solve this, we require to find the value of an immediate annuity of £1 per annum, at that rate of interest; this is found by Smart's Tables to be £12·65132, and if we multiply this amount into the rent-charge we have 12·65132 × 140 = £1771·184 for the value of the immediate equivalent.

We may also work out the same result by Thoman's Tables —using logarithms.

Thus, taking same term and rate,

Comp. log. a^n = 1·1021358
Log. 140 = 2·1461280
Log. 1771·184 = 3·2482638 = the same amount

as that above given, or £1771. 3*s*. 8*d*.

A little consideration will suffice to shew that these formulæ will apply to other questions of money interests. For instance, the computations will apply if the question is:—What is the present value of an immediate annuity for 17 years, in any property, if it is required to make an interest of 3½ per cent. per annum? for a person who is liable to pay an annual rent-charge, if he rids himself of the liability

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by paying down a certain sum, does, in effect, purchase to himself an annuity equal in amount to the rent-charge he was before paying. Other applications of the same principle will readily suggest themselves to the enquiring mind.

If the result of the computation be first obtained, while treating the annuity as being one single yearly payment, though it be, in fact, really divided into quarterly payments, or half-yearly payments, we may find the increased value under the latter circumstances very simply by Thoman's Tables.

EXAMPLE 2.

Question. A property yields a yearly rent of £860: what is it worth as a perpetuity when the rent is paid yearly; also when paid half-yearly; and when paid quarterly? Interest at the rate of $7\frac{1}{2}$ per cent. per annum.

1st. When paid yearly.

Comp. log. a^n	$= 1{\cdot}1249387$
Log. 860	$= 2{\cdot}9344985$
Log. £11,466·66	$= 4{\cdot}0594372$ = the Value.

2ndly. When paid half-yearly.

Log. of 1st value = 11,466·66	$= 4{\cdot}0594372$
+ Q_2 equivalent	$= 0{\cdot}0080676$
Log. £11,681·664	$= 4{\cdot}0675048$ = the Value.

To prove the second computation, it is sufficient to shew that the 1st value is increased by an amount = to the value of a perpetuity of $\frac{1}{2}$ year's interest on $\frac{1}{2}$ the annuity, at $7\frac{1}{2}$ per cent. as before; viz. £16·125.

Then	Comp. log. a^n	$= 1{\cdot}1249387$
	Log. 16·125	$= 1{\cdot}2074997$
	Log. £215	$= 2{\cdot}3324384$ = the Value; being

the amount by which the 1st value is increased in the 2nd computation: viz. 11,466·66 + 215 = £11,681·66.

3rdly. What is the value when the annuity is paid quarterly, the same rate of interest being allowed?

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Log. of 1st value = 4·0594372
+ Q_4 equivalent = ·0121951

Log. £11,793·216 = 4·0716323 = the Value; being the value when the annuity is paid quarterly.

To prove the 3rd computation the proceeding is more intricate; but it may be shewn that the 1st value, £11,466·66, is increased by the perpetuity of the following amounts, viz.:

1st. $\frac{3}{4}$ interest on 1 quarter of the annuity
= £12·09375 = in value £161·249

2nd. $\frac{1}{2}$ interest on 1 quarter of the annuity
= £8·0625 = in value £107·500

3rd. $\frac{1}{4}$ interest on 1 quarter of the annuity
= 4·03125 = in value £53·735

and by the compound interest on the quarter's interest on the quarter's interest on the quarters of the annuity } = £4·072

Then, Amount of Value when paid yearly = £11,466·660

Total Value as per 3rd computation = £11,793 216

Example 3.

The Valuation of Freehold Property with Minerals immediately productive.

What is the Value of an Estate of 400 acres, the minerals of which are just beginning to be worked, the fair estimated output per annum of coal being 120,000 tons (=400 tons per day for 300 days) at a royalty of, say, 10*d.* per ton; and the estimated duration of the same being 80 years? This would produce an annuity of £5000 for 80 years. The surface is being let, as farm land and rough pasturage, at £250 a year. Interest on capital to be allowed at 8 per cent. per annum; and capital to be recouped at 3½ per cent. per annum; interest on purchase money of surface being at the rate of 4 per cent. per annum, and in perpetuity.

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Then, the surface will thus be worth 25 years' purchase, or a total derived thus: $250 \times 25 = 6{,}250$ £6,250. 0

The annuity of £5000 for 80 years, at 8 per cent. per annum, and to recoup at 3½ per cent. per annum, is worth in present money the sum total of £60,690. 15. 0

Total Value £66,940. 15. 0

The formula by which the second value is derived is that given by Thoman in his treatise, and is as follows:

$$V = \frac{a}{t' + \frac{a^n}{r^n}},$$

in which V is the value; a the annuity; t' the rate per cent. to be made on purchase money; a^n the annuity which £1 will purchase for that term, and at rate of recoupment; and r^n the amount of £1 at the end of the term, and at the same rate.

Then applying this formula to the foregoing case we have the following values:

Logarithms.		Nat. Numbers.
Log. a^n	$= 8{\cdot}5726961$	
Log. r^n	$= 1{\cdot}1952280$	
$a^n r^{-n}$	$= 7{\cdot}3774681 =$	$0{\cdot}0023845$
		$+ t' = 0{\cdot}08$

Log. $t' + \frac{a^n}{r^n} = 8{\cdot}9158475 =$ . . . . . $= 0{\cdot}0823845$

Log. $a = 5{,}000 = 3{\cdot}6989700$

Log. of $V = 4{\cdot}7831225 =$ £60,690·75, or £60,690. 15*s.* 0*d.*

= purchase money of the annuity.

We may check the above computation by working out the question by the rules given by Hardy as in Inwood's Tables at page 179.

1st. by Smart's Tab. 3, $(a)^{80} = 419{\cdot}30678$

5000

Product = 2096533·9

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2nd. $(a)^{80} = 419{\cdot}30678$
$\times t' = \quad {\cdot}08$
Product $= 33{\cdot}5445424$
$+ \ 1$
Sum $= 34{\cdot}5445424$

3rd.
$\frac{2096533{\cdot}9}{34{\cdot}5445424} = £60{,}690{\cdot}75 = V$ the value as before.

Then, the interest on this value at 8 per cent. per annum will amount to.....4th. ..... 4855·26
giving for amortisement at $3\frac{1}{2}\%$ $(= s)$ 144·74
Total annuity £5,000·00

And to prove the sufficiency of the amortisement we have, by following the same rule,—

5th. Smart's Tab. I.
$r^{80} = 15\ 67573$
$- \ 1{\cdot}$
Diff. $= 14{\cdot}67573$

6th. Log. $14{\cdot}67573 = 1{\cdot}1666016$
Log. $s = 144{\cdot}74 = 2{\cdot}1605886$
C' Log. rate $\cdot035 = 11{\cdot}4559320$
Log. $60{,}690{\cdot}71 = 4{\cdot}7831222$ = the capital recouped at the end of the term of 80 years.

The foregoing estimate of quantity of coal would require a total thickness of 25 ft. or thereabouts, over the whole area of the property.

Example 4.

Freehold Property with Minerals, being partly immediately productive, and partly deferred, and comprising the following lots, viz.:

Lot A. Surface rental of 350 acres, equal to a perpetuity and let at a yearly sum of £145, net.

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Lot B. The upper veins of Coal producing 200 tons per day, or 60,000 tons per annum, let at 9*d.* per ton royalty; and calculated to yield this quantity for a further term of 18 years.

Lot C. The lower veins of Coal which from their favourable position are likely to be productive in 15 years, and then to yield an output of 300 tons per day, or 90,000 tons per annum, for a term of 65 years, and to let at 1*s.* per ton royalty.

Lot D. Freehold groundrents from houses built, amounting to £200 per annum, for 75 years unexpired term of the leases.

Lot E. Royalties or wayleaves yielding, at 1*d.* per ton, £80 per annum; and estimated so to continue for a further term of 12 years.

Then supposing interest to be allowed on the several lots as follows, viz:—

Lot A. 4 per cent. per annum as a perpetuity,
Lot B. 8 per cent. per an. on Capital, and to recoup at $3\frac{1}{2}$ %,
Lot C. 10 „ „ „ „ „ „ 3 %,
Lot D. 7 „ „ „ „ „ „ $3\frac{1}{2}$ %,
Lot E. 10 „ „ „ „ „ „ 3 %,

the following will be the values: the same notation and rules being applied as in Example 3.

The Value of Lot A will then be $145 \times 25 = £3{,}625.\ 0s.\ 0d.$

Lot B. Annuity for 18 years £2,250.
Interest on Capital 8 per cent.
Interest to recoup $3\frac{1}{2}$ per cent.

	Logarithms.	Nat. Numbers.
Log. a^{18}	$= 8{\cdot}8797657$	
Log. r^{18}	$= 0{\cdot}2689262$	
Log. $a^{18}r^{-18}$	$= 8{\cdot}6108395$	$= \ldots\ldots\ldots\ldots 0{\cdot}0408168$
		$+ t' = 0{\cdot}08$
Log. $t' + \frac{a^{18}}{r^{18}}$	$= 9{\cdot}0821269$	$= \ldots\ldots\ldots\ldots 0{\cdot}1208168$
Log. 2,250	$= 3{\cdot}3521825$	
Log. of Value	$= 4{\cdot}2700556$	$= £18.623{\cdot}26.$

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Checking by Hardy's rules as in Ex. 3,

1st. Smart's Tab. 3, $(a)^{18} = 24{\cdot}49969$
$2{,}250$
Product $= 55124{\cdot}3025$

2nd. $(a)^{18} = 24{\cdot}49969$
$\times t' = \quad{\cdot}08$
Prod. $= 1{\cdot}9599752$
$+ 1{\cdot}$
Sum $= 2{\cdot}9599752$

3rd. $\frac{55124{\cdot}3025}{2{\cdot}9599752} = 18{,}623{\cdot}23 =$ Value.

4th. Int. on Value at $8\ \frac{8}{8} = 1489{\cdot}8584$
Amort. to recoup $3\frac{1}{2}\ \frac{8}{8} = 760{\cdot}1416$
The annuity $= £2{,}250{\cdot}0000$

5th. Smart's Tab. 1. $r^{18} = 1{\cdot}85749$
$- 1{\cdot}$
Diff. $= 0{\cdot}85749$

Then 6th. Log. $\cdot85749 = 9{\cdot}9332291$
Log. $760{\cdot}1416 = 2{\cdot}8808944$
C^t Log. $\cdot035 = 11{\cdot}4559320$
Log. $18{,}623{\cdot}25 = 4{\cdot}2700555$ = the capital reproduced.

Lot C. The annuity for 65 years equals £4,500.
Interest on Capital = 10 per cent.
Interest to recoup = 3 per cent.
Period the annuity is deferred = 15 years.

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	Logarithms.	
	$=8\cdot5458736$	
	$=0\cdot8344196$	Nat. Numbers.
	$7\cdot7114540=$	.....$0\cdot0051458$
		$+t'=0\cdot10$
$t'+\frac{a^{65}}{r^{65}}=9\cdot0217900=$		.....Sum$=\cdot1051458$
$4{,}500$	$=3\cdot6532125$	
Log. of V	$=4\cdot6314225=$	Value, treated as "immediate," $=$ £42,797·9.

Checked by Hardy's rules,

1st. Smart's Tab. 3, $(a)^{65}=194\cdot3328$

$4{,}500$

Product $=874497\cdot60$

2nd. $(a)^{65}=194\cdot3328$

$\times t'=\cdot10$

Prod. $=19\cdot43328$

$+\ 1\cdot$

Sum $=20\cdot43328$

3rd. $\frac{874497\cdot6}{20\cdot433280}=42{,}797\cdot71=$ Value, as "immediate."

4th. Int. on Value at $10\,\%=4279\cdot771$

Amort. to recoup at $3\,\%=220\cdot229$

Total annuity £4,500·000

5th. Smart's Tab. 1. $r^{65}=6\cdot830$

$-1\cdot$

Diff. $=5\cdot830$

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6th. Log. 5·83 = 0·7656686
Log. 220·229 = 2·3428746
C^t Log. ·03 = 11·5228787
Log. 42,797·85 = 4·6314219 = the capital reproduced.

But as this annuity is deferred for 15 years (the first payment coming due in the 16th year) the above value has to be discounted for that term; and supposing that 8 per cent. per annum discount is allowed for it we have to proceed as follows. The interest at 8 per cent. per annum on £42,797·9 is £3,423·832.

Then (by Thoman's) Log. 3,423·832 = 3·5345164
÷ by Log. a^{15} = 9·0675527
Log. 29,374· = 4·4669637

∴ 42,797·9 − 29,374 = £13,423·9 = the value of the deferred annuity of Lot C treated on the terms indicated.

Lot D. The annuity for 75 years = £200.
Interest on Capital = 7 per cent.
Interest to recoup = 3½ per cent.

Logarithms.
Log. a^{75} = 8·5782860
Log. r^{75} = 1·1205262 Nat. Numbers.
Log. $a^{75}r^{-75}$ = 7·4577598 = ·0028692
$+ t' = ·07$
Log. $t' + \frac{a^{75}}{r^{75}}$ = 8·8625440 = ... Sum = ·0728692
Log. 200 = 2·3010300
Log. V = 3·4384860 = £2,744·64 = Value

By Hardy's rules,
1st. $(a)^{75}$ = 348·53001
200
Product = 69706·002

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2nd. $(a)^{75} = 348{\cdot}53001$
$\times t' = \quad {\cdot}07$
Prod. $= 24{\cdot}3971$
$+ \quad 1{\cdot}$
Sum $= 25{\cdot}3971$

3rd. $\frac{69{,}706{\cdot}002}{25{\cdot}3971} = £2{,}744{\cdot}64 =$ Value as above.

4th. Then Int. on Value at $7\,\%$ $= 192{\cdot}1248$
Amort. to recoup at $3\frac{1}{2}\,\%$ $= \quad 7{\cdot}8752$
Total annuity $= £200{\cdot}0000$

5th. $r^{75} = 13{\cdot}19855$
$- \quad 1{\cdot}$
Diff. $= 12{\cdot}19855$

6th. Log. $12{\cdot}19855 = 1{\cdot}0863082$
Log. $\quad 7{\cdot}8752 = 0{\cdot}8962616$
C^t Log. $\quad {\cdot}035 = 11{\cdot}4559320$
Log. $2{,}744{\cdot}74 = 3{\cdot}4385018 =$ the capital reproduced at the end of 75 years.

Lot E. The annuity for 12 years equals £80.
Interest on Capital $= 10$ per cent.
Interest to recoup $= 3$ per cent.

	Logarithms.	Nat. Numbers.
Log. a^{12}	$= 9{\cdot}0020022$	
Log. r^{12}	$= 0{\cdot}1540467$	
Log. $a^{12}r^{-12}$	$= 8{\cdot}8479555 =$	$\ldots\ldots\ldots\ldots = {\cdot}070462$
		$+t' = {\cdot}10$
Log. $t' + \frac{a^{12}}{r^{12}}$	$= 9{\cdot}2316273 =$	$\ldots\ldots$ Sum $= {\cdot}170462$
Log. 80	$= 1{\cdot}9030900$	
Log. V	$= 2{\cdot}6714627 = £469{\cdot}313$	the Value.

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Check by Hardy's rules.

1st. $(a)^{12} = 14{\cdot}192$
$\times \quad 80$
Product $= 1135{\cdot}36$

2nd. $(a)^{12} = 14{\cdot}192$
$\times t' = \quad {\cdot}10$
Prod. $= 1{\cdot}4192$
$+ 1'$
Sum $= 2{\cdot}4192$

3rd. $\frac{1135{\cdot}36}{2{\cdot}4192} = £469{\cdot}313 =$ Value as above.

Then 4th. Interest on Value at 10 % $= 46{\cdot}9312$
Amort. to recoup at 3 % $= 33{\cdot}0688$
Total annuity $= £80{\cdot}0000$

5th. $r^{12} = 1{\cdot}4258$
$- 1'$
Diff. $= {\cdot}4258$

6th. Log. ·4258 = 9·6292057
Log. 33·0688 = 1·5194185
C^t Log. ·03 = 11·5228787
Log. 469·35 = 2·6715029 = the capital reproduced at the end of the term.

SUMMARY OF VALUES.

	£	s.	d.
The Value of Lot A =	3,625	0	0
„ Value of Lot B =	18,623	5	2
„ Value of Lot C =	13,423	18	0
„ Value of Lot D =	2,744	12	9
„ Value of Lot E =	469	6	3
Total Value =	38,886	2	2

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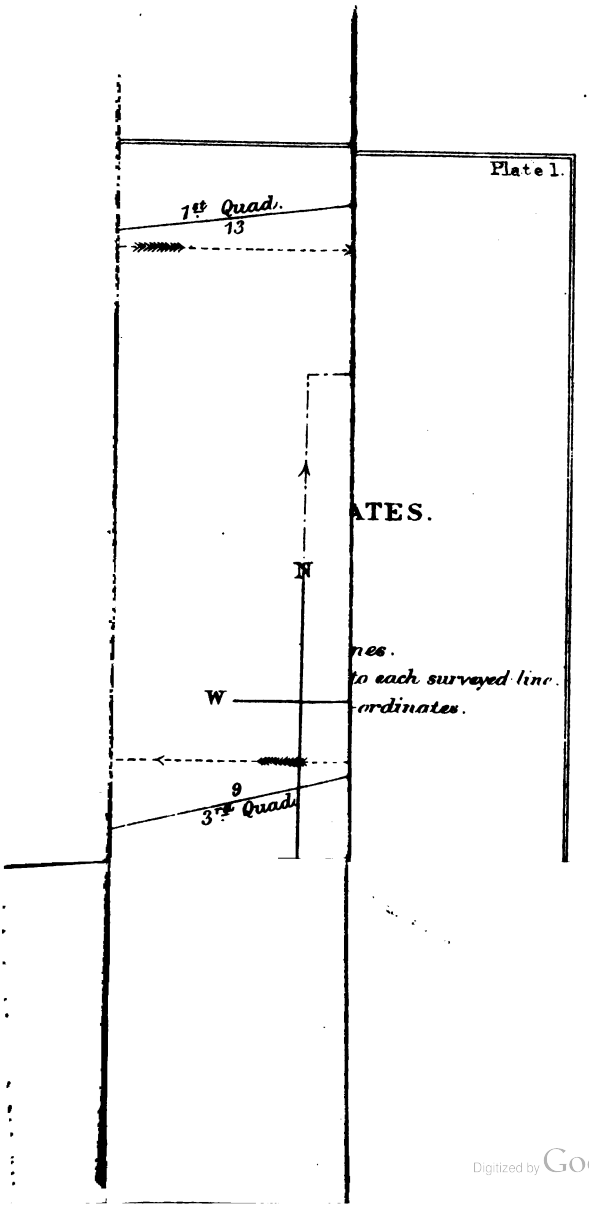

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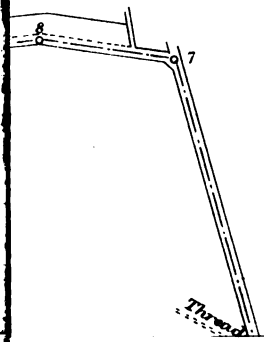

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CHAPTER XIII.

THE TRAVERSE TABLES.

(DESCRIBED IN CHAPTER VII, PAGES 21—37)

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Minutes.	Dist. 100. Lat. Per.	Dist. 100. Dep. Base.	Dist. 200. Lat. Per.	Dist. 200. Dep. Base.	Dist. 300. Lat. Per.	Dist. 300. Dep. Base.	Dist. 400. Lat. Per.	Dist. 400. Dep. Base.	Dist. 500. Lat. Per.	Dist. 500. Dep. Base.	
0	100·00	0·00	200·00	0·00	300·00	0·00	400·00	0·00	500·00	0·00	60
3	99·99	0·08	199·99	0·17	299·99	0·26	399·99	0·35	499·99	0·43	57
6	99·99	0·17	199·99	0·35	299·99	0·52	399·99	0·70	499·99	0·87	54
9	99·99	0·26	199·99	0·52	299·99	0·78	399·99	1·05	499·99	1·30	51
12	99·99	0·35	199·99	0·70	299·99	1·04	399·99	1·39	499·99	1·74	48
15	99·99	0·44	199·99	0·87	299·99	1·30	399·99	1·74	499·99	2·17	45
18	99·99	0·52	199·99	1·04	299·99	1·57	399·99	2·09	499·99	2·61	42
21	99·99	0·61	199·99	1·21	299·99	1·83	399·99	2·44	499·99	3·05	39
24	99·99	0·70	199·99	1·39	299·99	2·09	399·98	2·79	499·98	3·49	36
27	99·99	0·78	199·99	1·56	299·99	2·35	399·98	3·14	499·98	3·92	33
30	99·99	0·87	199·99	1·74	299·98	2·61	399·98	3·49	499·98	4·36	30
33	99·99	0·96	199·99	1·91	299·98	2·87	399·98	3·84	499·97	4·79	27
36	99·99	1·05	199·99	2·09	299·98	3·14	399·97	4·18	499·97	5·23	24
39	99·99	1·13	199·98	2·26	299·98	3·40	399·97	4·53	499·96	5·66	21
42	99·99	1·22	199·98	2·44	299·97	3·66	399·96	4·88	499·96	6·10	18
45	99·99	1·31	199·98	2·61	299·97	3·92	399·96	5·23	499·95	6·54	15
48	99·99	1·39	199·98	2·79	299·96	4·18	399·95	5·58	499·95	6·98	12
51	99·99	1·48	199·97	2·96	299·96	4·44	399·95	5·93	499·94	7·41	9
54	99·98	1·57	199·97	3·14	299·96	4·71	399·94	6·28	499·93	7·85	6
57	99·98	1·66	199·97	3·31	299·95	4·97	399·94	6·63	499·93	8·28	3
60	99·98	1·74	199·97	3·49	299·95	5·23	399·94	6·98	499·92	8·72	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	600·00	0·00	700·00	0·00	800·00	0·00	900·00	0·00	1000·00	0·00	60
3	599·99	0·52	699·99	0·61	799·99	0·69	899·99	0·78	999·99	0·87	57
6	599·99	1·04	699·99	1·22	799·99	1·39	899·99	1·57	999·99	1·74	54
9	599·99	1·56	699·99	1·83	799·99	2·09	899·99	2·35	999·99	2·62	51
12	599·99	2·09	699·99	2·44	799·99	2·79	899·99	3·14	999·99	3·49	48
15	599·99	2·61	699·99	3·05	799·99	3·49	899·99	3·92	999·99	4·36	45
18	599·99	3·14	699·99	3·66	799·98	4·19	899·98	4·71	999·98	5·24	42
21	599·99	3·66	699·98	4·27	799·98	4·89	899·98	5·49	999·98	6·11	39
24	599·98	4·18	699·98	4·88	799·98	5·58	899·97	6·28	999·97	6·98	36
27	599·98	4·70	699·97	5·49	799·97	6·28	899·97	7·06	999·96	7·85	33
30	599·97	5·23	699·97	6·10	799·97	6·98	899·96	7·85	999·96	8·72	30
33	599·97	5·75	699·96	6·71	799·96	7·68	899·95	8·63	999·95	9·60	27
36	599·96	6·28	699·96	7·33	799·95	8·38	899·95	9·42	999·94	10·47	24
39	599·96	6·80	699·95	7·94	799·94	9·07	899·94	10·21	999·93	11·34	21
42	599·95	7·33	699·94	8·55	799·94	9·77	899·93	11·00	999·92	12·22	18
45	599·95	7·85	699·94	9·16	799·93	10·47	899·92	11·78	999·91	13·09	15
48	599·94	8·37	699·93	9·77	799·92	11·17	899·91	12·57	999·90	13·96	12
51	599·93	8·90	699·92	10·38	799·91	11·87	899·90	13·35	999·89	14·83	9
54	599·92	9·42	699·91	10·99	799·90	12·57	899·89	14·14	999·87	15·71	6
57	599·91	9·95	699·90	11·61	799·89	13·26	899·87	14·92	999·86	16·58	3
60	599·90	10·47	699·89	12·22	799·87	13·96	899·86	15·71	999·84	17·45	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·98	1·74	199·97	3·49	299·95	5·23	399·94	6·98	499·92	8·72	60
3	99·98	1·83	199·96	3·66	299·95	5·49	399·93	7·33	499·91	9·16	57
6	99·98	1·92	199·96	3·84	299 94	5·76	399·92	7·67	499·91	9·60	54
9	99·98	2·01	199·96	4·01	299·94	6·02	399·92	8·02	499·90	10·03	51
12	99·97	2·09	199·95	4·18	299·93	6·28	399·91	8·37	499·89	10·47	48
15	99·97	2·18	199·95	4·35	299·93	6·54	399·90	8·72	499·88	10·90	45
18	99·97	2·27	199·95	4·53	299·92	6·80	399·89	9·07	499·87	11·34	42
21	99·97	2·35	199·94	4·70	299·91	7·06	399·88	9·42	499·86	11·77	39
24	99·97	2·44	199·94	4·88	299·91	7·33	399·88	9·77	499·85	12·21	36
27	99·96	2·53	199·93	5·05	299·90	7·59	399·87	10·12	499·84	12·64	33
30	99·96	2·62	199·93	5·23	299·90	7·85	399·86	10·47	499·83	13·08	30
33	99·96	2·70	199·92	5·40	299·89	8·11	399·85	10·82	499·82	13·52	27
36	99·96	2·79	199·92	5·58	299·88	8·37	399·84	11·17	499·80	13·96	24
39	99·96	2·88	199·91	5·75	299·87	8·63	399·83	11·52	499·79	14·39	21
42	99·95	2·97	199·91	5·93	299·86	8·89	399·82	11·86	499·78	14·83	18
45	99·95	3·05	159·90	6·10	299·86	9·15	399·81	12·21	499·76	15·26	15
48	99·95	3·14	199·90	6·28	299·85	9·42	399·80	12·56	499·75	15·70	12
51	99·95	3·23	199·89	6·45	299·84	9·68	399·79	12·91	499·74	16·13	9
54	99·94	3·31	199·89	6·63	299·83	9·94	399·78	13·26	499·72	16·57	6
57	99·94	3·40	199·88	6·80	299·82	10·20	399·76	13·61	499·71	17·01	3
60	99·94	3·49	199·87	6·98	299·81	10·47	399·75	13·96	499·69	17·45	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	599·90	10·47	699·89	12·22	799·87	13·96	899·86	15·71	999·84	17·45	60
3	599·90	10·99	699·88	12·83	799·86	14·65	899·85	16·49	999·83	18·32	57
6	599·89	11·51	699·87	13·44	799·85	15·35	899·83	17·27	999·81	19·19	54
9	599·88	12·03	699·86	14·05	799·84	16·05	899·81	18·05	999·80	20·06	51
12	599·86	12·56	699·84	14·66	799·82	16·75	899·80	18·84	999·78	20·94	48
15	599·85	13·08	699·83	15·27	799·81	17·45	899·78	19·62	999·76	21·81	45
18	599·84	13·61	699·82	15·88	799·79	18·15	899·76	20·41	999·74	22·68	42
21	599·83	14·13	699·80	16·49	799·78	18·85	899·75	21·20	999·72	23·55	39
24	599·82	14·65	699·79	17·10	799·76	19·54	899·73	21·99	999·70	24·43	36
27	599·81	15·17	699·77	17·71	799·74	20·24	899·71	22·77	999·68	25·30	33
30	599·79	15·70	699·76	18·32	799·72	20·94	899·69	23·56	999·66	26·17	30
33	599·78	16·22	699·74	18·93	799·71	21·64	899·67	24·34	999·63	27·04	27
36	599·76	16·75	699·72	19·54	799·69	22·33	899·65	25·12	999·61	27·92	24
39	599·75	17·27	699·70	20·15	799·67	23·03	899·62	25·91	999·58	28·79	21
42	599·73	17·80	699·69	20·76	799·64	23·73	899·60	26·70	999·56	29·66	18
45	599·72	18·32	699·67	21·37	799·62	24·42	899·57	27·48	999·53	30·53	15
48	599·70	18·84	699·65	21·98	799·60	25·12	899·55	28·27	999·50	31·41	12
51	599·68	19·36	699·63	22·59	799·58	25·82	899·53	29·05	999·48	32·28	9
54	599·67	19·89	699·61	23·20	799·56	26·52	899·50	29·84	999·45	33·15	6
57	599·65	20·41	699·59	23·81	799·54	27·22	899·48	30·62	999·42	34·02	3
60	599·63	20·94	699·57	24·42	799·51	27·92	899·45	31·41	999·39	34·90	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·94	3·49	199·87	6·98	299·81	10·47	399·75	13·96	499·69	17·45	60
3	99·93	3·58	199·87	7·15	299·80	10·73	399·74	14·31	499·68	17·88	57
6	99·93	3·66	199·86	7·33	299·80	10·99	399·73	14·65	499·66	18·32	54
9	99·93	3·75	199·86	7·50	299·79	11·25	399·72	15·00	499·65	18·75	51
12	99·92	3·84	199·85	7·67	299·78	11·51	399·70	15·35	499·63	19·19	48
15	99·92	3·93	199·84	7·84	299·77	11·77	399·69	15·70	499·61	19·62	45
18	99·92	4·01	199·84	8·02	299·76	12·03	399·67	16·05	499·60	20·06	42
21	99·91	4·10	199·83	8·19	299·75	12·29	399·66	16·40	499·58	20·49	39
24	99·91	4·19	199·82	8·37	299·73	12·56	399·65	16·75	499·56	20·93	36
27	99·91	4·27	199·81	8·54	299·72	12·82	399·63	17·10	499·54	21·36	33
30	99·90	4·36	199·81	8·72	299·71	13·08	399·62	17·44	499·52	21·80	30
33	99·90	4·45	199·80	8·89	299·70	13·34	399·60	17·79	499·50	22·24	27
36	99·89	4·54	199·79	9·07	299·69	13·60	399·59	18·14	499·48	22·68	24
39	99·89	4·62	199·78	9·24	299·68	13·86	399·57	18·49	499·46	23·11	21
42	99·89	4·71	199·78	9·42	299·66	14·13	399·55	18·84	499·44	23·55	18
45	99·88	4·80	199·77	9·59	299·65	14·39	399·54	19·19	499·42	23·98	15
48	99·88	4·88	199·76	9·77	299·64	14·65	399·52	19·54	499·40	24·42	12
51	99·87	4·97	199·75	9·94	299·63	14·91	399·50	19·89	499·38	24·85	9
54	99·87	5·06	199·74	10·11	299·61	15·17	399·49	20·23	499·36	25·29	6
57	99·86	5·15	199·73	10·28	299·60	15·43	399·47	20·58	499·33	25·72	3
60	99·86	5·23	199·72	10·46	299·59	15·70	399·45	20·93	499·31	26·16	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	599·63	20·94	699·57	24·42	799·51	27·92	899·45	31·41	999·39	34·90	60
3	599·61	21·46	699·55	25·03	799·49	28·62	899·42	32·19	999·36	35·77	57
6	599·60	21·98	699·53	25·65	799·46	29·31	899·39	32·98	999·33	36·64	54
9	599·58	22·50	699·50	26·26	799·44	30·01	899·36	33·76	999·30	37·51	51
12	599·56	23·03	699·48	26·87	799·41	30·71	899·33	34·54	999·26	38·39	48
15	599·54	23·55	699·46	27·48	799·38	31·41	899·30	35·32	999·23	39·26	45
18	599·52	24·07	699·43	28·09	799·35	32·10	899·27	36·11	999·19	40·13	42
21	599·49	24·59	699·41	28·70	799·32	32·80	899·24	36·89	999·16	41·00	39
24	599·47	25·12	699·38	29·31	799·30	33·50	899·21	37·68	999·13	41·87	36
27	599·45	25·64	699·36	29·92	799·27	34·20	899·17	38·46	999·09	42·75	33
30	599·43	26·17	699·33	30·53	799·24	34·89	899·14	39·25	999·05	43·62	30
33	599·40	26·69	699·30	31·14	799·21	35·59	899·10	40·03	999·01	44·49	27
36	599·38	27·21	699·28	31·75	799·17	36·29	899·07	40·82	998·97	45·36	24
39	599·36	27·74	699·25	32·36	799·14	36·99	899·03	41·60	998·93	46 23	21
42	599·33	28·26	699·22	32·97	799·11	37·68	899·00	42·39	998·89	47·11	18
45	599·31	28·78	699·19	33·58	799·08	38·38	898·96	43·17	998·84	47·98	15
48	599·28	29·31	699·16	34·19	799·04	39·08	898·92	43·96	998·80	48·85	12
51	599·26	29·83	699·13	34·80	799·01	39·78	898·88	44·74	998·76	49·72	9
54	599·23	30·35	699·10	35·41	798·97	40·47	898·84	45·53	998·72	50·59	6
57	599·20	30·88	699·07	36·02	798·94	41·17	898·80	46·31	998·67	51·46	3
60	599·18	31·40	699·04	36·63	798·90	41·86	898·76	47·10	998·63	52·34	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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3 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·86	5·23	199·72	10·46	299·59	15·70	399·45	20·93	499·31	26·16	60
3	99·86	5·32	199·71	10·63	299·57	15·96	399·43	21·28	499·29	26·59	57
6	59·85	5·41	199·71	10·81	299·56	16·22	399·41	21·63	499·26	27·03	54
9	99·85	5·49	199·70	10·98	299·55	16·48	399·39	21·98	499·24	27·47	51
12	99·84	5·58	199·69	11·16	299·53	16·74	399·37	22·32	499·22	27·91	48
15	99·84	5·67	199·68	11·33	299·52	17·00	399·35	22·67	499·19	28·34	45
18	99·83	5·76	199·67	11·51	299·50	17·27	399·33	23·02	499·17	28·78	42
21	99·83	5·84	199·66	11·68	299·49	17·53	399·31	23·37	499·14	29·21	39
24	99·82	5·93	199·65	11·86	299·47	17·79	399·29	23·72	499·12	29·65	36
27	99·82	6·02	199·64	12·03	299·45	18·05	399·27	24·07	499·09	30·08	33
30	99·81	6·10	199·63	12·21	299·44	18·31	399·25	24·41	499·06	30·52	30
33	99·81	6·19	199·61	12·38	299·42	18·57	399·23	24·76	499·04	30·95	27
36	99·80	6·28	199·60	12·55	299·41	18·83	399·21	25·11	499·01	31·39	24
39	99·80	6·36	199·59	12·72	299·39	19·09	399·19	25·46	498·98	31·82	21
42	99·79	6·45	199·58	12·90	299·37	19·35	399·16	25·81	498·96	32·26	18
45	99·78	6·54	199·57	13·07	299·36	19·61	399·14	26·16	498·93	32·69	15
48	99·78	6·63	199·56	13·25	299·34	19·88	399·12	26·51	498·90	33·13	12
51	99·77	6·71	199·55	13·42	299·32	20·14	399·09	26·86	498·87	33·56	9
54	99·77	6·80	199·54	13·60	299·30	20·40	399·07	27·20	498·84	34·00	6
57	99·76	6·89	199·52	13·77	299·29	20·66	399·05	27·55	498·81	34·43	3
60	99·75	6·97	199·51	13·95	299·27	20·92	399·02	27·90	498·78	34·87	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	599·18	31·40	699·04	36·63	798·90	41·86	898·76	47·10	998·63	52·34	60
3	599·15	31·92	699·01	37·24	798·86	42·56	898·72	47·88	998·58	53·21	57
6	599·12	32·44	698·97	37·85	798·83	43·26	898·68	48·67	998·54	54·08	54
9	599·09	32·96	698·94	38·46	798·79	43·06	898·64	49·45	998·49	54·95	51
12	599·06	33·49	698·91	39·07	798·75	44·65	898·60	50·24	998·44	55·82	48
15	599·03	34·01	698·87	39·68	798·71	45·35	898·55	51·02	998·39	56·69	45
18	599·00	34·54	698·84	40·29	798·67	46·05	898·51	51·80	998·34	57·56	42
21	598·97	35·06	698·80	40·90	798·63	46·75	898·46	52·58	998·29	58·43	39
24	598·94	35·58	698·76	41·51	798·59	47·44	898·41	53·37	998·24	59·31	36
27	598·91	36·10	698·73	42·12	798·55	48·14	898·37	54·15	998·18	60·18	33
30	598·88	36·63	698·69	42·73	798·51	48·84	898·32	54·94	998·13	61·05	30
33	598·85	37·15	698·65	43·34	798·46	49·54	898·27	55·72	998·08	61·92	27
36	598·81	37·67	698·62	43·95	798·42	50·23	898·22	56·51	998·02	62·79	24
39	598·78	38·19	698·58	44·56	798·38	50·93	898·17	57·29	997·97	63·66	21
42	598·75	38·72	698·54	45·17	798·33	51·62	898·12	58·08	997·91	64·53	18
45	598·71	39·24	698·50	45·78	798·28	52·32	898·07	58·86	997·86	65·40	15
48	598·68	39·76	698·46	46·39	798·24	53·01	898·02	59·64	997·80	66·27	12
51	598·64	40·28	698·42	47·00	798·19	53·71	897·97	60·42	997·74	67·14	9
54	598·61	40·81	698·38	47·61	798·15	54·41	897·92	61·21	997·68	68·01	6
57	598·57	41·33	698·33	48·22	798·10	55·11	897·86	61·99	997·62	68·88	3
60	598·54	41·85	698·29	48·83	798·05	55·80	897·81	62·78	997·56	69·75	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·75	6·97	199·51	13·95	299·27	20·92	399·02	27·90	498·78	34·87	60
3	99·75	7·06	199·50	14·12	299·25	21·18	399·00	28·25	498·75	35·30	57
6	99·74	7·15	199·49	14·30	299·23	21·45	398·97	28·60	498·72	35·74	54
9	99·74	7·24	199·47	14·47	299·21	21·71	398·95	28·95	498·69	36·18	51
12	99·73	7·32	199·46	14·64	299·19	21·97	398·92	29·30	498·66	36·62	48
15	99·72	7·41	199·45	14·81	299·17	22·23	398·90	29·65	498·62	37·05	45
18	99·72	7·50	199·43	14·99	299·15	22·49	398·87	29·99	498·59	37·40	42
21	99·71	7·58	199·42	15·17	299·13	22·75	398·85	30·34	498·56	37·92	39
24	99·70	7·67	199·41	15·34	299·11	23·01	398·82	30·68	498·53	38·36	36
27	99·70	7·76	199·39	15·51	299·09	23·27	398·79	31·03	498·49	38·79	33
30	99·69	7·85	199·38	15·69	299·07	23·53	398·76	31·38	498·46	39·23	30
33	99·68	7·93	199·37	15·86	299·05	23·79	398·74	31·73	498·42	39·66	27
36	99·68	8·02	199·35	16·03	299·03	24·06	398·71	32·08	498·39	40·10	24
39	99·67	8·11	199·34	16·20	299·01	24·32	398·68	32·43	498·35	40·53	21
42	99·66	8·19	199·33	16·38	298·99	24·58	398·65	32·77	498·32	40·97	18
45	99·65	8·28	199·31	16·55	298·97	24·84	398·62	33·12	498·28	41·40	15
48	99·65	8·37	199·30	16·73	298·95	25·10	398·60	33·47	498·24	41·84	12
51	99·64	8·45	199·28	16·90	298·92	25·36	398·57	33·82	498·21	42·27	9
54	99·63	8·54	199·27	17·08	298·90	25·62	398·54	34·16	498·17	42·71	6
57	99·63	8·63	199·25	17·25	298·88	25·88	398·51	34·51	498·13	43·14	3
60	99·62	8·71	199·24	17·43	298·86	26·14	398·48	34·86	498·10	43·58	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	598·54	41·85	698·29	48·83	798·05	55·80	897·81	62·78	997·56	69·75	60
3	598·50	42·37	698·25	49·44	798·00	56·50	897·75	63·56	997·50	70·63	57
6	598·46	42·90	698·21	50·05	797·95	57·19	897·70	64·34	997·44	71·50	54
9	598·42	43·42	698·16	50·66	797·90	57·89	897·64	65·12	997·37	72·37	51
12	598·39	43·94	698·12	51·27	797·85	58·59	897·58	65·91	997·31	73·24	48
15	598·35	44·46	698·07	52·88	797·80	59·29	897·53	66·69	997·25	74·11	45
18	598·31	44·98	698·03	52·49	797·75	59·98	897·47	67·47	997·18	74·98	42
21	598·27	45·50	697·98	53·10	797·69	60·68	897·41	68·25	997·12	75·85	39
24	598·23	46·03	697·94	53·70	797·64	61·37	897·35	69·04	997·05	76·72	36
27	598·19	46·55	697·89	54·31	797·59	62·07	897·29	70·82	996·98	77·59	33
30	598·15	47·07	697·84	54·92	797·53	62·77	897·23	70·61	996·92	78·46	30
33	598·11	47·60	697·79	55·33	797·48	63·47	897·16	71·39	996·85	79·33	27
36	598·06	48·12	697·74	56·14	797·42	64·16	897·10	72·18	996·78	80·20	24
39	598·02	48·64	697·70	56·75	797·36	64·86	897·04	72·96	996·71	81·07	21
42	597·98	49·16	697·65	57·35	797·31	65·55	896·97	73·75	996·64	81·94	18
45	597·94	49·68	697·59	57·96	797·25	66·25	896·91	74·53	996·56	82·81	15
48	597·89	50·20	697·54	58·57	797·19	66·94	896·84	75·31	996·49	83·68	12
51	597·85	50·72	697·49	59·18	797·13	67·64	896·78	76·09	996·42	84·55	9
54	597·80	51·25	697·44	59·79	797·07	68·33	896·71	76·87	996·34	85·42	6
57	597·76	51·77	697·39	60·40	797·01	69·03	896·64	77·65	996·27	86·29	3
60	597·72	52·29	697·33	61·01	796·95	69·72	896·58	78·44	996·19	87·15	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·62	8·71	199·24	17·43	298·86	26·14	398·48	34·86	498·10	43·58	60
3	99·61	8·80	199·22	17·60	298·83	26·40	398·45	35·21	498·06	44·01	57
6	99·60	8·89	199·21	17·78	298·81	26·66	398·41	35·56	498·02	44·45	54
9	99·60	8·98	199·19	17·95	298·79	26·92	398·38	35·91	497·98	44·88	51
12	99·59	9·06	199·18	18·12	298·76	27·19	398·35	36·25	497·94	45·31	48
15	99·58	9·15	199·16	18·29	298·74	27·45	398·32	36·60	497·90	45·74	45
18	99·57	9·24	199·14	18·47	298·72	27·71	398·29	36·95	497·86	46·18	42
21	99·56	9·32	199·13	18·64	298·69	27·97	398·26	37·30	497·82	46·61	39
24	99·55	9·41	199·11	18·82	298·67	28·23	398·22	37·64	497·78	47·05	36
27	99·55	9·50	199·09	18·99	298·64	28·49	398·19	37·99	497·74	47·48	33
30	99·54	9·58	199·08	19·17	298·62	28·75	398·16	38·34	497·70	47·92	30
33	99·53	9·67	199·06	19·34	298·59	29·01	398·12	38·69	497·66	48·35	27
36	99·52	9·76	199·04	19·52	298·57	29·27	398·09	39·03	497·61	48·79	24
39	99·51	9·84	199·03	19·69	298·54	29·53	398·06	39·38	497·57	49·22	21
42	99·50	9·93	199·01	19·86	298·52	29·79	398·02	39·73	497·53	49·66	18
45	99·50	10·02	198·99	20·03	298·49	30·05	397·99	40·08	497·48	50·09	15
48	99·49	10·10	198·97	20·21	298·46	30·31	397·95	40·42	497·44	50·53	12
51	99·48	10·19	198·96	20·38	298·44	30·57	397·92	40·77	497·40	50·96	9
54	99·47	10·28	198 94	20·55	298·41	30·83	397·88	41·12	497·35	51·40	6
57	99·46	10·36	198·92	20·72	298·38	31·09	397·84	41·47	497·31	51·83	3
60	99·45	10·45	198·90	20·90	298·36	31·36	397·81	41·81	497·26	52·26	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	597·72	52·29	697·33	61·01	796·95	69·72	896·58	78·44	996·19	87·15	60
3	597·67	52·81	697·28	61·62	796·89	70·42	896·51	79·22	996·11	88·02	57
6	597·62	53·33	697·23	62·22	796·83	71·11	896·44	80·01	996·04	88·89	54
9	597·58	53·85	697·17	62·83	796·77	71·81	896·37	80·79	995·96	89·76	51
12	597·53	54·38	697·12	63·44	796·70	72·50	896·30	81·57	995·88	90·63	48
15	597·48	55·90	697·06	64·05	796·64	73·20	896·22	82·35	995·80	91·50	45
18	597·43	55·42	697·00	64·66	796·58	73·89	896·15	83·13	995·72	92·37	42
21	597·39	55·94	696·95	65·27	796·51	74·59	896·08	83·91	995·64	93·24	39
24	597·33	56·46	696·89	65·87	796·45	75·28	896·01	84·70	995·56	94·11	36
27	597·29	56·98	696·83	66·48	796·38	75·98	895·93	85·48	995·48	94·98	33
30	597·24	57·51	696·78	67·09	796·32	76·68	895·86	86·26	995·39	95·84	30
33	597·19	58·03	696·72	67·70	796·25	77·38	895·78	87·04	995·31	96·71	27
36	597·13	58·55	696·66	68·31	796·18	78·07	895·70	87·82	995·23	97·58	24
39	597·08	59·07	696·60	68·92	796·11	78·77	895·63	88·60	995·14	98·45	21
42	597·03	59·59	696·54	69·52	796·04	79·46	895·55	89·38	995·05	99·32	18
45	596·98	60·11	696·48	70·13	795·97	80·15	895·47	90·16	994·97	100·19	15
48	596·93	60·63	696·42	70·74	795·90	80·84	895·39	90·95	994·88	101·05	12
51	596·87	61·15	696·35	71·35	795·83	81·54	895·31	91·73	994·79	101·92	9
54	596·82	61·67	696·29	71·95	795·76	82·23	895·23	92·51	994·70	102·79	6
57	596·77	62·19	696·23	72·56	795·69	82·93	895·15	93·29	994·61	103·66	3
60	596·71	62·71	696·16	73·17	795·62	83·62	895·07	94·07	994·52	104·53	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·45	10·45	198·90	20·90	298·36	31·36	397·81	41·81	497·26	52·26	60
3	99·44	10·54	198·88	21·07	298·33	31·62	397·77	42·16	497·21	52·69	57
6	99·43	10·62	198·87	21·25	298·30	31·88	397·73	42·50	497·17	53·13	54
9	99·42	10·71	198·85	21·42	298·27	32·14	397·70	42·85	497·12	53·56	51
12	99·41	10·80	198·83	21·60	298·24	32·40	397·66	43·20	497·07	54·00	48
15	99·40	10·89	198·81	21·77	298·21	32·66	397·62	43·55	497·03	54·43	45
18	99·39	10·97	198·79	21·95	298·19	32·92	397·58	43·89	496·98	54·87	42
21	99·38	11·06	198·77	22·12	298·16	33·18	397·54	44·24	496·93	55·30	39
24	99·37	11·15	198·75	22·29	298·13	33·44	397·51	44·59	496·88	55·73	36
27	99·36	11·23	198·73	22·46	298·10	33·70	397·47	44·94	496·83	56·16	33
30	99·35	11·32	198·71	22·64	298·07	33·96	397·43	45·28	496·78	56·60	30
33	99·34	11·41	198·69	22·81	298·04	34·22	397·39	45·63	496·73	57·03	27
36	99·33	11·49	198·67	22·98	298·01	34·48	397·35	45·97	496·68	57·47	24
39	99·32	11·58	198·65	23·15	297·98	34·74	397·31	46·32	496·63	57·90	21
42	99·31	11·67	198·63	23·33	297·95	35·00	397·27	46·67	496·58	58·34	18
45	99·30	11·75	198·61	23·50	297·92	35·26	397·23	47·02	496·53	58·77	15
48	99·29	11·84	198·59	23·68	297·89	35·52	397·18	47·36	496·48	59·20	12
51	99·28	11·93	198·57	23·85	297·86	35·78	397·14	47·71	496·43	59·63	9
54	99·27	12·01	198·55	24·03	297·83	36·04	397·10	48·05	496·38	60·07	6
57	99·26	12·10	198·53	24·20	297·79	36·30	397·06	48·40	496·33	60·50	3
60	99·25	12·19	198·51	24·38	297·76	36·56	397·02	48·75	496·27	60·93	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	596·71	62·71	696·16	73·17	795·62	83·62	895·07	94·07	994·52	104·53	60
3	596·66	63·23	696·10	73·78	795·54	84·31	894·99	94·85	994·43	105·39	57
6	596·60	63·76	696·04	74·38	795·47	85·01	894·90	95·63	994·34	106·26	54
9	596·55	64·28	695·97	74·99	795·39	85·70	894·82	96·41	994·24	107·13	51
12	596·49	64·80	695·90	75·60	795·32	86·40	894·74	97·20	994·15	108·00	48
15	596·43	65·32	695·84	76·21	795·24	87·09	894·65	97·98	994·05	108·87	45
18	596·37	65·84	695·77	76·81	795·17	87·79	894·56	98·76	993·96	109·73	42
21	596·32	66·36	695·70	77·42	795·09	88·48	894·48	99·54	993·86	110·60	39
24	596·26	66·88	695·64	78·03	795·01	89·17	894·39	100·32	993·77	111·47	36
27	596·20	67·40	695·57	78·64	794·93	89·86	894·30	101·10	993·67	112·33	33
30	596·14	67·92	695·50	79·24	794·86	90·56	894·21	101·88	993·57	113·20	30
33	596·08	68·44	695·43	79·85	794·77	91·25	894·12	102·66	993·47	114·07	27
36	596·02	68·96	695·36	80·46	794·69	91·95	894·03	103·44	993·37	114·94	24
39	595·96	69·48	695·29	81·07	794·61	92·65	893·94	104·22	993·27	115·80	21
42	595·90	70·00	695·22	81·67	794·53	93·34	893·85	105·00	993·17	116·67	18
45	595·84	70·52	695·14	82·28	794·45	94·03	893·76	105·78	993·07	117·54	15
48	595·78	71·04	695·07	82·88	794·37	94·72	893·67	106·56	992·96	118·40	12
51	595·72	71·56	695·00	83·49	794·29	95·42	893·57	107·34	992·86	119·27	9
54	595·65	72·08	694·93	84·10	794·20	96·11	893·48	108·12	992·76	120·13	6
57	595·59	72·60	694·85	84·71	794·12	96·80	893·38	108·90	992·65	121·00	3
60	595·53	73·12	694·78	85·31	794·03	97·50	893·29	109·68	992·54	121·87	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base	
0	99·25	12·19	198·51	24·38	297·76	36·56	397·02	48·75	496·27	60·93	60
3	99·24	12·27	198·49	24·55	297·73	36·82	396·97	49·10	496·22	61·37	57
6	99·23	12·36	198·46	24·72	297·70	37·08	396·93	49·44	496·17	61·80	54
9	99·22	12·45	198·44	24·90	297·67	37·34	396·89	49·79	496·11	62·23	51
12	99·21	12·53	198·42	25·07	297·63	37·60	396·84	50·13	496·06	62·67	48
15	99·20	12·62	198·40	25·24	297·60	37·86	396·80	50·48	496·00	63·10	45
18	99·19	12·71	198·38	25·42	297·57	38·12	396·76	50·83	495·95	63·53	42
21	99·18	12·79	198·36	25·59	297·53	38·38	396·71	51·17	495·89	63·97	39
24	99·17	12·88	198·33	25·76	297·50	38·64	396·67	51·52	495·83	64·40	36
27	99·15	12·97	198·31	25·93	297·47	38·90	396·62	51·87	495·78	64·83	33
30	99·13	13·05	198·28	26·11	297·43	39·16	396·58	52·21	495·72	65·26	30
33	99·12	13·14	198·26	26·28	297·40	39·42	396·53	52·56	495·66	65·70	27
36	99·11	13·22	198·24	26·45	297·36	39·68	396·48	52·90	495·61	66·13	24
39	99·10	13·31	198·22	26·63	297·33	39·94	396·44	53·25	495·55	66·56	21
42	99·09	13·40	198·20	26·80	297·29	40·20	396·39	53·60	495·49	66·99	18
45	99·07	13·48	198·17	26·97	297·26	40·46	396·35	53·94	495·43	67·42	15
48	99·06	13·57	198·15	27·14	297·22	40·72	396·30	54·29	495·37	67·86	12
51	99·05	13·66	198·12	27·32	297·19	40·98	396·25	54·63	495·31	68·29	9
54	99·04	13·74	198·10	27·49	297·15	41·23	396·20	54·98	495·25	68·72	6
57	99·03	13·83	198·08	27·66	297·12	41·49	396·15	55·32	495·19	69·15	3
60	99·02	13·92	198·05	27·84	297·08	41·75	396·11	55·67	495·13	69·59	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	595·53	73·12	694·78	85·31	794·03	97·50	893·29	109·68	992·54	121·87	60
3	595·46	73·64	694·71	85·92	793·95	98·19	893·19	110·46	992·44	122·73	57
6	595·40	74·16	694·63	86·52	793·86	98·88	893·10	111·24	992·33	123·60	54
9	595·33	74·68	694·55	87·13	793·78	99·57	893·00	112·02	992·22	124·47	51
12	595·27	75·20	694·48	87·73	793·69	100·27	892·90	112·80	992·11	125·33	48
15	595·20	75·72	694·40	88·34	793·60	100·96	892·80	113·58	992·00	126·20	45
18	595·13	76·24	694·32	88·94	793·51	101·65	892·70	114·36	991·89	127·06	42
21	595·07	76·76	694·25	89·55	793·42	102·34	892·60	115·14	991·78	127·93	39
24	595·00	77·28	694·17	90·16	793·33	103·04	892·50	115·92	991·67	128·79	36
27	594·93	77·80	694·09	90·76	793·24	103·73	892·40	116·69	991·56	129·66	33
30	594·86	78·32	694·01	91·37	793·15	104·42	892·30	117·47	991·44	130·52	30
33	594·80	78·83	693·93	91·97	793·06	105·11	892·20	118·25	991·33	131·39	27
36	594·73	79·35	693·85	92·58	792·97	105·80	892·09	119·03	991·21	132·26	24
39	594·66	79·87	693·77	93·19	792·88	106·50	891·99	119·81	991·10	133·12	21
42	594·59	80·39	693·69	93·79	792·78	107·19	891·88	120·59	990·98	133·98	18
45	594·52	80·91	693·60	94·40	792·69	107·88	891·78	121·36	990·86	134·85	15
48	594·45	81·43	693·52	95·00	792·60	108·57	891·67	122·14	990·75	135·71	12
51	594·38	81·95	693·44	95·60	792·50	109·26	891·56	122·92	990·63	136·58	9
54	594·30	82·47	693·35	96·21	792·41	109·95	891·46	123·70	990·51	137·44	6
57	594·23	82·99	693·27	96·82	792·31	110·65	891·35	124·48	990·39	138·31	3
60	594·16	83·50	693·18	97·42	792·21	111·34	891·24	125·26	990·27	139·17	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	99·02	13·92	198·05	27·84	297·08	41·75	396·11	55·67	495·13	69·59	60
3	99·01	14·00	198·03	28·01	297·04	42·01	396·06	56·02	495·07	70·02	57
6	99·00	14·09	198·00	28·18	297·01	42·27	396·01	56·36	495·01	70·45	54
9	98·99	14·18	197·98	28·36	296·97	42·53	395·96	56·71	494·95	70·88	51
12	98·98	14·26	197·95	28·53	296·93	42·79	395·91	57·05	494·89	71·31	48
15	98·96	14·35	197·93	28·70	296·89	43·05	395·86	57·40	494·82	71·75	45
18	98·95	14·43	197·90	28·87	296·86	43·31	395·81	57·74	494·76	72·18	42
21	98·94	14·52	197·88	29·05	296·82	43·57	395·76	58·09	494·70	72·61	39
24	98·93	14·61	197·85	29·22	296·78	43·83	395·71	58·44	494·63	73·04	36
27	98·91	14·69	197·83	29·39	296·74	44·08	395·66	58·78	494·57	73·47	33
30	98·90	14·78	197·80	29·57	296·70	44·34	395·61	59·12	494·51	73·90	30
33	98·89	14·87	197·78	29·74	296·66	44·60	395·55	59·47	494·44	74·34	27
36	98·87	14·95	197·75	29·91	296·63	44·86	395·50	59·81	494·38	74·77	24
39	98·86	15·04	197·72	30·08	296·59	45·12	395·45	60·16	494·31	75·20	21
42	98·85	15·13	197·70	30·25	296·55	45·38	395·40	60·51	494·25	75·63	18
45	98·84	15·21	197·67	30·43	296·51	45·64	395·34	60·85	494·18	76·06	15
48	98·82	15·30	197·64	30·60	296·47	45·90	395·29	61·19	494·11	76·49	12
51	98·81	15·38	197·62	30·77	296·43	46·16	395·24	61·54	494·05	76·92	9
54	98·79	15·47	197·59	30·94	296·39	46·41	395·18	61·88	493·98	77·36	6
57	98·78	15·56	197·56	31·12	296·35	46·67	395·13	62·23	493·91	77·79	3
60	98·77	15·64	197·54	31·29	296·30	46·93	395·07	62·57	493·84	78·22	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	594·16	83·50	693·18	97·42	792·21	111·34	891·24	125·26	990·27	139·17	60
3	594·09	84·02	693·10	98·03	792·11	112·03	891·13	126·03	990·14	140·04	57
6	594·01	84·54	693·01	98·63	792·02	112·72	891·02	126·81	990·02	140·90	54
9	593·94	85·06	692·93	99·24	791·92	113·41	890·91	127·59	989·90	141·76	51
12	593·86	85·58	692·84	99·84	791·82	114·10	890·80	128·37	989·77	142·63	48
15	593·79	86·09	692·75	100·44	791·72	114·79	890·69	129·14	989·65	143·49	45
18	593·71	86·61	692·67	101·05	791·62	115·48	890·57	129·92	989·52	144·36	42
21	593·64	87·13	692·58	101·65	791·52	116·17	890·46	130·70	989·40	145·22	39
24	593·56	87·65	692·49	102·26	791·42	116·86	890·34	131·47	989·27	146·08	36
27	593·48	88·17	692·40	102·86	791·31	117·56	890·23	132·25	989·14	146·94	33
30	593·41	88·69	692·31	103·47	791·21	118·25	890·11	133·03	989·01	147·81	30
33	593·33	89·20	692·22	104·07	791·11	118·94	890·00	133·80	988·88	148·67	27
36	593·25	89·72	692·13	104·67	791·00	119·63	889·88	134·58	988·75	149·53	24
39	593·17	90·24	692·04	105 28	790·90	120·32	889·76	135·36	988·62	150·40	21
42	593·09	90·76	691·95	105·88	790·80	121·01	889·64	136·13	988·49	151·26	18
45	593·02	91·27	691·85	106·48	790·69	121·70	889·52	136·91	988·36	152·12	15
48	592·94	91·79	691·76	107·09	790·58	122·39	889·41	137·69	988·23	152·98	12
51	592·86	92·31	691·66	107·69	790·47	123·08	889·28	138·46	988·09	153·85	9
54	592·77	92·83	691·57	108·30	790·37	123·77	889·16	139·24	987·96	154·71	6
57	592·69	93·34	691·47	108·90	790·26	124·46	889·04	140·01	987·82	155·57	3
60	592·61	93·86	691·38	109·50	790·15	125·15	888·92	140·79	987·69	156·43	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	98·77	15·64	197·54	31·29	296·30	46·93	395·07	62·57	493·84	78·22	60
3	98·75	15·73	197·51	31·46	296·26	47·19	395·02	62·92	493·77	78·65	57
6	98·74	15·81	197·48	31·63	296·22	47·45	394·96	63·26	493·71	79·08	54
9	98·73	15·90	197·45	31·81	296·18	47·71	394·91	63·61	493·64	79·51	51
12	98·71	15·99	197·43	31·98	296·14	47·96	394·85	63·95	493·57	79·94	48
15	98·70	16·07	197·39	32·15	296·10	48·22	394·80	64·30	493·50	80·37	45
18	98·68	16·16	197·37	32·32	296·06	48·48	394·74	64·64	493·43	80·80	42
21	98·67	16·25	197·34	32·50	296·01	48·75	394·68	64·99	493·36	81·23	39
24	98·66	16·33	197·31	32·67	295·97	49·00	394·63	65·33	493·28	81·66	36
27	98·64	16·42	197·28	32·84	295·93	49·25	394·57	65·68	493·21	82·09	33
30	98·63	16·50	197·26	33·01	295·88	49·52	394·51	66·02	493·14	82·52	30
33	98·61	16·59	197·23	33·18	295·84	49·77	394·46	66·36	493·07	82·95	27
36	98·60	16·68	197·20	33·36	295·80	50·03	394·40	66·71	493·00	83·38	24
39	98·58	16·76	197·17	33·53	295·75	50·29	394·34	67·05	492·92	83·81	21
42	98·57	16·85	197·14	33·70	295·71	50·55	394·28	67·40	492·85	84·24	18
45	98·55	16·93	197·11	33·87	295·67	50·81	394·22	67·74	492·78	84·67	15
48	98·54	17·02	197·08	34·04	295·62	51·06	394·16	68·08	492·70	85·10	12
51	98·52	17·11	197·05	34·22	295·58	51·32	394·10	68·43	492·63	85·53	9
54	98·51	17·19	197·02	34·39	295·53	51·58	394·04	68·77	492·55	85·96	6
57	98·49	17·28	196·99	34·56	295·49	51·84	393·98	69·12	492·48	86·39	3
60	98·48	17·36	196·96	34·73	295·44	52·09	393·92	69·46	492·40	86·82	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	592·61	93·86	691·38	109·50	790·15	125·15	888·92	140·79	987·69	156·43	60
3	592·53	94·38	691·28	110·11	790·04	125·84	888·80	141·57	987·55	157·30	57
6	592·45	94·89	691·19	110·71	789·93	126·53	888·67	142·34	987·41	158·16	54
9	592·37	95·41	691·09	111·31	789·82	127·21	888·55	143·12	987·27	159·02	51
12	592·28	95·93	690·99	111·92	789·71	127·90	888·42	143·80	987·14	159·88	48
15	592·20	96·45	690·90	112·52	789·60	128·59	888·30	144·67	987·00	160·74	45
18	592·11	96·96	690·80	113·12	789·48	129·28	888·17	145·44	986·85	161·60	42
21	592·03	97·48	690·70	113·72	789·37	129·97	888·04	146·22	986·71	162·46	39
24	591·94	97·99	690·60	114·33	789·26	130·66	887·91	147·00	986·57	163·32	36
27	591·86	98·51	690·50	114·93	789·14	131·35	887·79	147·77	986·43	164·19	33
30	591·77	99·03	690·40	115·53	789·03	132·04	887·66	148·54	986·28	165·05	30
33	591·68	99·54	690·30	116·14	788·91	132·73	887·53	149·32	986·14	165·91	27
36	591·60	100·06	690·20	116·74	788·80	133·41	887·40	150·09	986·00	166·77	24
39	591·51	100·58	690·09	117·34	788·68	134·10	887·27	150·87	985·85	167·63	21
42	591·42	101·09	689·99	117·94	788·56	134·79	887·13	151·64	985·70	168·49	18
45	591·33	101·61	689·89	118·54	788·44	135·48	887·00	152·41	985·55	169·35	15
48	591·24	102·12	689·79	119·15	788·32	136·17	886·86	153·19	985·41	170·21	12
51	591·15	102·64	689·68	119·75	788·21	136·85	886·73	153·96	985·26	171·07	9
54	591·06	103·16	689·58	120·35	788·09	137·54	886·60	154·74	985·11	171·93	6
57	590·97	103·67	689·47	120·95	787·97	138·23	886·46	155·51	984·96	172·79	3
60	590·88	104·19	689·36	121·55	787·84	138·92	886·33	156·28	984·81	173·65	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	98·48	17·36	196·96	34·73	295·44	52·09	393·92	69·46	492·40	86·82	60
3	98·46	17·45	196·93	34·90	295·40	52·35	393·86	69·80	492·33	87·25	57
6	98·45	17·54	196·90	35·08	295·35	52·61	393·80	70·15	492·25	87·68	54
9	98·43	17·62	196·87	35·25	295·30	52·87	393·74	70·49	492·17	88·11	51
12	98·42	17·71	196·84	35·42	295·26	53·13	393·68	70·83	492·10	88·54	48
15	98·40	17·80	196·81	35·59	295·21	53·38	393·62	71·18	492·02	88·97	45
18	98·39	17·88	196·78	35·76	295·17	53·64	393·55	71·52	491·94	89·40	42
21	98·37	17·97	196·75	35·93	295·12	53·90	393·49	71·86	491·86	89·83	39
24	98·36	18·05	196·71	36·11	295·07	54·16	393·43	72·21	491·78	90·26	36
27	98·34	18·14	196·68	36·28	295·02	54·41	393·36	72·55	491·71	90·69	33
30	98·32	18·23	196·65	36·45	294·97	54·67	393·30	72·89	491·63	91·12	30
33	98·31	18·31	196·62	36·62	294·93	54·93	393·24	73·24	491·55	91·55	27
36	98·29	18·40	196·59	36·79	294·88	55·19	393·17	73·58	491·47	91·98	24
39	98·28	18·49	196·55	36·96	294·83	55·44	393·11	73·92	491·39	92·40	21
42	98·26	18·57	196·52	37·13	294·78	55·70	393·04	74·27	491·31	92·83	18
45	98·24	18·66	196·49	37·30	294·73	55·96	392·98	74·61	491·22	93·26	15
48	98·23	18·74	196·46	37·48	294·68	56·21	392·91	74·95	491·14	93·69	12
51	98·21	18·83	196·42	37·65	294·63	56·47	392·85	75·30	491·06	94·12	9
54	98·19	18·91	196·39	37·82	294·58	56·73	392·78	75·64	490·98	94·55	6
57	98·18	19·00	196·36	37·99	294·53	56·99	392·72	75·98	490·90	94·98	3
60	98·16	19·08	196·32	38·16	294·48	57·24	392·65	76·32	490·81	95·40	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	590·88	104·19	689·36	121·55	787·84	138·92	886·33	156·28	984·81	173·65	60
3	590·79	104·70	689·26	122·15	787·72	139·60	886·19	157·06	984·65	174·51	57
6	590·70	105·22	689·15	122·76	787·60	140·29	886·05	157·83	984·50	175·37	54
9	590·61	105·73	689·04	123·36	787·48	140·98	885·91	158·60	984·35	176·22	51
12	590·52	106·25	688·94	123·96	787·36	141·67	885·78	159·38	984·19	177·08	48
15	590·42	106·76	688·83	124·56	787·23	142·35	885·64	160·15	984·04	177·94	45
18	590·33	107·28	688·72	125·16	787·11	143·04	885·50	160·92	983·88	178·80	42
21	590·23	107·79	688·61	125·76	786·98	143·73	885·35	161·69	983·73	179·66	39
24	590·14	108·31	688·50	126·36	786·86	144·41	885·21	162·47	983·57	180·52	36
27	590·04	108·83	688·39	126·96	786·73	145·10	885·07	163·24	983·41	181·38	33
30	589·95	109·34	688·28	127·56	786·60	145·79	884·93	164·01	983·25	182·23	30
33	589·85	109·86	688·17	128·16	786·48	146·47	884·79	164·78	983·09	183·09	27
36	589·76	110·37	688·05	128·76	786·35	147·16	884·64	165·56	982·94	183·95	24
39	589·66	110·89	687·94	129·36	786·22	147·85	884·50	166·33	982·77	184·81	21
42	589·56	111·40	687·83	129·96	786·09	148·53	884·35	167·10	982·61	185·67	18
45	589·47	111·91	687·71	130·56	785·96	149·22	884·21	167·87	982·45	186·52	15
48	589·37	112·43	687·60	131·17	785·83	149·90	884·06	168·64	982·29	187·38	12
51	589·27	112·94	687·48	131·77	785·70	150·59	883·91	169·41	982·12	188·24	9
54	589·17	113·46	687·37	132·37	785·57	151·28	883·76	170·19	981·96	189·09	6
57	589·07	113·97	687·25	132·97	785·43	151·96	883·61	170·96	981·79	189·95	3
60	588·97	114·48	687·14	133·57	785·30	152·65	883·46	171·73	981·62	190·81	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	98·16	19·08	196·32	38·16	294·48	57·24	392·65	76·32	490·81	95·40	60
3	98·14	19·16	196·29	38·33	294·43	57·50	392·58	76·66	490·73	95·83	57
6	98·13	19·25	196·26	38·51	294·39	57·76	392·52	77·01	490·64	96·26	54
9	98·11	19·34	196·22	38·68	294·34	58·01	392·45	77·35	490·56	96·69	51
12	98·09	19·42	196·19	38·85	294·28	58·27	392·38	77·69	490·48	97·12	48
15	98·08	19·51	196·16	39·02	294·23	58·53	392·31	78·04	490·39	97·54	45
18	98·06	19·59	196·12	39·19	294·18	58·78	392·24	78·38	490·31	97·97	42
21	98·04	19·68	196·09	39·36	294·13	59·04	392·18	78·72	490·22	98·40	39
24	98·02	19·76	196·05	39·53	294·08	59·30	392·11	79·06	490·13	98·83	36
27	98·00	19·85	196·02	39·70	294·03	59·55	392·04	79·40	490·05	99·26	33
30	97·99	19·94	195·98	39·88	293·98	59·81	391·97	79·75	489·96	99·68	30
33	97·97	20·02	195·95	40·05	293·92	60·06	391·90	80·09	489·87	100·11	27
36	97·95	20·11	195·91	40·22	293·87	60·32	391·83	80·43	489·79	100·54	24
39	97·94	20·19	195·88	40·39	293·82	60·58	391·76	80·77	489·70	100·96	21
42	97·92	20·28	195·84	40·56	293·77	60·84	391·69	81·11	489·61	101·39	18
45	97·90	20·36	195·81	40·73	293·71	61·09	391·62	81·45	489·52	101·82	15
48	97·89	20·45	195·77	40·90	293·66	61·35	391·54	81·80	489·43	102·25	12
51	97·87	20·53	195·74	41·07	293·61	61·61	391·47	82·14	489·34	102·68	9
54	97·85	20·62	195·70	41·24	293·55	61·86	391·40	82·48	489·25	103·10	6
57	97·83	20·71	195·66	41·14	293·50	62·12	391·33	82·82	489·16	103·53	3
60	97·81	20·79	195·63	41·58	293·44	62·37	391·26	83·16	489·07	103·95	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

78 Deg.

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11 Deg.

Minutes.	Dist. 600. Lat. Per.	Dist. 600. Dep. Base.	Dist. 700. Lat. Per.	Dist. 700. Dep. Base.	Dist. 800. Lat. Per.	Dist. 800. Dep. Base.	Dist. 900. Lat. Per.	Dist. 900. Dep. Base.	Dist. 1000. Lat. Per.	Dist. 1000. Dep. Base.	
0	588·97	114·48	687·14	133·57	785·30	152·65	883·46	171·73	981·62	190·81	60
3	588·87	115·00	687·02	134·17	785·17	153·33	883·31	172·50	981·46	191·66	57
6	588·77	115·51	686·90	134·76	785·03	154·08	883·16	173·27	981·29	192·52	54
9	588·67	116·03	686·79	135·36	784·90	154·70	883·01	174·04	981·12	193·38	51
12	588·57	116·54	686·67	135·96	784·76	155·40	882·86	174·81	980·95	194·23	48
15	583·47	117·05	686·55	136·56	784·63	156·09	882·71	175·58	980·78	195·09	45
18	588·37	117·57	686·43	137·16	784·49	156·76	882·55	176·35	980·61	195·95	42
21	588·27	118·08	686·31	137·76	784·35	157·44	882·40	177·12	980·44	196·80	39
24	588·16	118·59	686·19	138·36	784·22	158·13	882·24	177·89	980·27	197·66	36
27	588·06	119·11	686·07	138·96	784·08	158·81	882·09	178·66	980·10	198·51	33
30	587·95	119·62	685·95	139·56	783·94	159·49	881·93	179·42	979·92	199·37	30
33	587·85	120·13	685·82	140·16	783·80	160·18	881·77	180·19	979·75	200·22	27
36	587·74	120·65	685·70	140·75	783·66	160·86	881·62	180·97	979·57	201·08	24
39	587·64	121·16	685·58	141·35	783·52	161·55	881·46	181·74	979·40	201·93	21
42	587·53	121·67	685·45	141·95	783·38	162·23	881·30	182·51	979·22	202·79	18
45	587·42	122·18	685·33	142·55	783·23	162·91	881·14	183·28	979·04	203·64	15
48	587·32	122·70	685·21	143·15	783·09	163·60	880·98	184·05	978·86	204·49	12
51	587·21	123·21	685·08	143·74	782·95	164·28	880·82	184·82	978·69	205·35	9
54	587·10	123·72	684·95	144·34	782·81	164·96	880·66	185·58	978·51	206·20	6
57	587·00	124·23	684·83	144·94	782·66	165·65	880·49	186·35	978·33	207·06	3
60	586·89	124·75	684·70	145·54	782·52	166·33	880·33	187·12	978·15	207·91	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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12 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	97·81	20·79	195·63	41·58	293·44	62·37	391·26	83·16	489·07	103·95	60
3	97·80	20·88	195·59	41·76	293·39	62·63	391·18	83·51	488·98	104·38	57
6	97·78	20·96	195·56	41·92	293·33	62·87	391·11	83·85	488·89	104·81	54
9	97·76	21·05	195·52	42·10	293·28	63·14	391·04	84·19	488·80	105·24	51
12	97·74	21·13	195·48	42·27	293·22	63·40	390·96	84·53	488·71	105·66	48
15	97·72	21·22	195·44	42·44	293·17	63·66	390·89	84·87	488·61	106·09	45
18	97·70	21·30	195·41	42·61	293·11	63·91	390·82	85·21	488·52	106·51	42
21	97·68	21·39	195·37	42·78	293·06	64·17	390·74	85·55	488·43	106·94	39
24	97·67	21·47	195·33	42·95	293·00	64·42	390·67	85·89	488·33	107·37	36
27	97·65	21·56	195·30	43·12	292·94	64·68	390·59	86·24	488·24	107·79	33
30	97·63	21·64	195·26	43·29	292·89	64·93	390·52	86·58	488·15	108·22	30
33	97·61	21·73	195·22	43·46	292·83	65·19	390·44	86·92	488·05	108·64	27
36	97·59	21·81	195·18	43·63	292·77	65·44	390·37	87·26	487·96	109·07	24
39	97·57	21·90	195·14	43·80	292·72	65·70	390·29	87·60	487·86	109·50	21
42	97·55	21·98	195·11	43·97	292·66	65·95	390·21	87·94	487·77	109·93	18
45	97·53	22·07	195·07	44·14	292·60	66·21	390·14	88·28	487·67	110·35	15
48	97·51	22·15	195·03	44·31	292·54	66·47	390·06	88·62	487·57	110·77	12
51	97·49	22·24	194·99	44·48	292·49	66·72	389·98	88·96	487·48	111·20	9
54	97·48	22·33	194·95	44·65	292·43	66·98	389·90	89·30	487·38	111·62	6
57	97·46	22·41	194·91	44·82	292·37	67·23	389·83	89·64	487·28	112·15	3
60	97·44	22·49	194·87	44·99	292·31	67·49	389·75	89·98	487·18	112·47	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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12 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	586·89	124·75	684·70	145·54	782·52	166·33	880·33	187·12	978·15	207·91	60
3	586·78	125·26	684·57	146·13	782·37	167·01	880·17	187·89	977·96	208·76	57
6	586·67	125·77	684·45	146·73	782·22	167·69	880·00	188·66	977·78	209·62	54
9	586·56	126·28	684·32	147·33	782·08	168·38	879·84	189·42	977·60	210·47	51
12	586·45	126·79	684·19	147·93	781·93	169·06	879·67	190·19	977·41	211·32	48
15	586·34	127·31	684·06	148·52	781·78	169·74	879·51	190·96	977·23	212·18	45
18	586·23	127·82	683·93	149·12	781·63	170·42	879·34	191·73	977·04	213·03	42
21	586·11	128·33	683·80	149·72	781·48	171·10	879·17	192·49	976·86	213·88	39
24	586·00	128·84	683·67	150·31	781·33	171·79	879·00	193·26	976·67	214·73	36
27	585·89	129·35	683·54	150·91	781·18	172·47	878·84	194·03	976·48	215·59	33
30	585·78	129·86	683·41	151·51	781·03	173·15	878·67	194·79	976·29	216·44	30
33	585·66	130·37	683·27	152·10	780·88	173·83	878·50	195·56	976·10	217·29	27
36	585·55	130·88	683·14	152·70	780·73	174·51	878·32	196·33	975·91	218·14	24
39	585·43	131·40	683·01	153·30	780·58	175·19	878·15	197·09	975·72	218·99	21
42	585·32	131·91	682·87	153·89	780·43	175·88	877·98	197·86	975·53	219·85	18
45	585·20	132·42	682·74	154·49	780·27	176·56	877·81	198·63	975·34	220·70	15
48	585·09	132·93	682·60	155·08	780·12	177·24	877·63	199·39	975·15	221·55	12
51	584·97	133·44	682·47	155·68	779·96	177·92	877·46	200·16	974·95	222·40	9
54	584·86	133·95	682·33	156·27	779·81	178·60	877·28	200·92	974·76	223·25	6
57	584·74	134·46	682·19	156·87	779·65	179·28	877·11	201·70	974·56	224·11	3
60	584·62	134·97	682·06	157·46	779·49	179·96	876·93	202·45	974·37	224·95	0
	Base.	Per.	Base.	Per	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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13 Deg.

Minutes.	Dist. 100. Lat. Per.	Dist. 100. Dep. Base.	Dist. 200. Lat. Per.	Dist. 200. Dep. Base.	Dist. 300. Lat. Per.	Dist. 300. Dep. Base.	Dist. 400. Lat. Per.	Dist. 400. Dep. Base.	Dist. 500. Lat. Per.	Dist. 500. Dep. Base.	
0	97·44	22·49	194·87	44·99	292·31	67·49	389·75	89·98	487·18	112·47	60
3	97·42	22·58	194·83	45·16	292·25	67·74	389·67	90·32	487·09	112·90	57
6	97·40	22·66	194·79	45·33	292·19	67·99	389·59	90·66	486·99	113·32	54
9	97·38	22·75	194·75	45·50	292·13	68·25	389·51	91·00	486·89	113·75	51
12	97·36	22·83	194·71	45·67	292·07	68·51	389·43	91·34	486·79	114·17	48
15	97·34	22·92	194·67	45·84	292·01	68·76	389·35	91·68	486·69	114·60	45
18	97·32	23·00	194·63	46·01	291·95	69·01	389·27	92·02	486·59	115·02	42
21	97·30	23·09	194·59	46·18	291·89	69·27	389·19	92·36	486·49	115·45	39
24	97·28	23·17	194·55	46·35	291·83	69·52	389·11	92·70	486·39	115·87	36
27	97·26	23·26	194·51	46·52	291·77	69·78	389·03	93·04	486·29	116·30	33
30	97·24	23·34	194·47	46·69	291·71	70·03	388·95	93·38	486·18	116·72	30
33	97·22	23·43	194·43	46·86	291·65	70·29	388·86	93·72	486·08	117·15	27
36	97·20	23·51	194·39	47·03	291·59	70·54	388·78	94·06	485·98	117·57	24
39	97·18	23·60	194·35	47·20	291·52	70·80	388·70	94·40	485·88	117·99	21
42	97·15	23·68	194·31	47·37	291·46	71·05	388·62	94·74	485·77	118·42	18
45	97·13	23·77	194·27	47·54	291·40	71·31	388·54	95·07	485·67	118·84	15
48	97·11	23·85	194·23	47·71	291·34	71·56	388·45	95·41	485·57	119·27	12
51	97·09	23·94	194·18	47·88	291·28	71·81	388·37	95·75	485·46	119·69	9
54	97·07	24·02	194·14	48·05	291·21	72·07	388·29	96·09	485·36	120·11	6
57	97·05	24·11	194·10	48·22	291·15	72·32	388·20	96·43	485·25	120·54	3
60	97·03	24·19	194·06	48·39	291·09	72·58	388·12	96·77	485·15	120·96	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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13 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	584·62	134·97	682·06	157·46	779·49	179·96	876·93	202·45	974·37	224·95	60
3	584·50	135·48	681·92	158·06	779·34	180·64	876·75	203·22	974·17	225·80	57
6	584·38	135·99	681·78	158·65	779·18	181·32	876·58	203·99	973·97	226·65	54
9	584·26	136·50	681·64	159·25	779·02	182·00	876·40	204·75	973·78	227·50	51
12	584·15	137·01	681·50	159·85	778·86	182·68	876·22	205·51	973·58	228·35	48
15	584·03	137·52	681·36	160·44	778·70	183·36	876·04	206·28	973·38	229·20	45
18	583·91	138·03	681·22	161·03	778·54	184·04	875·86	207·04	973·18	230·05	42
21	583·78	138·54	681·08	161·63	778·38	184·72	875·68	207·81	972·98	230·90	39
24	583·66	139·05	680·94	162·22	778·22	185·40	875·50	208·57	972·77	231·75	36
27	583·54	139·56	680·80	162·82	778·06	186·08	875·31	209·34	972·57	232·60	33
30	583·42	140·07	680·66	163·41	777·89	186·76	875·13	210·10	972·37	233·45	30
33	583·30	140·57	680·51	164·00	777·73	187·44	874·95	210·86	972·16	234·29	27
36	583·17	141·08	680·37	164·60	777·57	188·11	874·76	211·62	971·96	235·14	24
39	583·05	141·59	680·23	165·19	777·40	188·79	874·57	212·39	971·75	235·99	21
42	582·93	142·10	680·08	165·79	777·24	189·47	874·39	213·15	971·55	236·84	18
45	582·80	142·61	679·94	166·38	777·07	190·15	874·21	213·92	971·34	237·69	15
48	582·68	143·12	679·80	166·97	776·91	190·83	874·02	214·68	971·13	238·53	12
51	582·55	143·63	679·65	167·57	776·74	191·50	873·83	215·44	970·92	239·38	9
54	582·43	144·14	679·50	168·16	776·57	192·18	873·64	216·20	970·72	240·23	6
57	582·30	144·64	679·35	168·75	776·40	192·86	873·46	216·97	970·51	241·07	3
60	582·18	145·15	679·21	169·34	776·23	193·54	873·27	217·73	970·30	241·92	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

76 Deg.

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14 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	97·03	24·19	194·06	48·39	291·09	72·58	388·12	96·77	485·15	120·96	60
3	97·01	24·28	194·02	48·55	291·02	72·83	388·03	97·11	485·04	121·38	57
6	96·99	24·36	193·97	48·72	290·96	73·08	387·95	97·44	484·94	121·81	54
9	96·96	24·45	193·93	48·89	290·90	73·34	387·86	97·78	484·83	122·23	51
12	96·94	24·53	193·89	49·06	290·83	73·59	387·78	98·12	484·72	122·65	48
15	96·92	24·62	193·84	49·23	290·77	73·85	387·69	98·46	484·61	123·08	45
18	96·90	24·70	193·80	49·40	290·70	74·10	387·60	98·80	484·51	123·50	42
21	96·88	24·78	193·76	49·57	290·64	74·35	387·52	99·14	484·40	123·92	39
24	96·86	24·87	193·72	49·74	290·57	74·61	387·43	99·48	484·29	124·34	36
27	96·84	24·95	193·67	49·91	290·51	74·86	387·34	99·81	484·18	124·77	33
30	96·81	25·04	193·63	50·08	290·44	75·11	387·26	100·15	484·07	125·19	30
33	96·79	25·12	193·58	50·25	290·38	75·37	387·17	100·49	483·96	125·61	27
36	96·77	25·21	193·54	50·42	290·31	75·62	387·08	100·83	483·85	126·03	24
39	96·75	25·29	193·50	50·58	290·25	75·87	386·99	101·16	483·74	126·46	21
42	96·73	25·37	193·45	50·75	290·18	76·13	386·91	101·50	483·63	126·88	18
45	96·70	25·46	193·41	50·92	290·11	76·38	386·82	101·84	483·52	127·30	15
48	96·68	25·54	193·36	51·09	290·05	76·63	386·73	102·18	483·41	127·72	12
51	96·66	25·63	193·32	51·26	289·98	76·89	386·64	102·51	483·30	128·14	9
54	96·64	25·71	193·27	51·43	289·91	77·14	386·55	102·85	483·19	128·57	6
57	96·62	25·80	193·23	51·60	289·84	77·39	386·46	103·19	483·07	128·99	3
60	96·59	25·88	193·18	51·76	289·78	77·65	386·37	103·53	482·96	129·41	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

75 Deg.

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14 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	582·18	145·15	679·21	169·34	776·23	193·54	873·27	217·73	970·29	241·92	60
3	582·05	145·66	679·06	169·94	776·07	194·21	873·07	218·49	970·08	242·77	57
6	581·92	146·17	678·91	170·53	775·90	194·89	872·88	219·25	969·87	243·61	54
9	581·79	146·68	678·76	171·12	775·73	195·57	872·69	220·01	969·66	244·46	51
12	581·67	147·18	678·61	171·71	775·55	196·24	872·50	220·77	969·44	245·31	48
15	581·54	147·69	678·46	172·31	775·38	196·92	872·31	221·54	969·23	246·15	45
18	581·41	148·20	678·31	172·90	775·21	197·60	872·11	222·30	969·01	247·00	42
21	581·28	148·71	678·16	173·49	775·04	198·27	871·92	223·06	968·80	247·84	39
24	581·15	149·21	678·01	174·08	774·86	198·95	871·72	223·82	968·58	248·69	36
27	581·02	149·72	677·85	174·67	774·69	199·63	871·53	224·58	968·36	249·53	33
30	580·89	150·23	677·70	175·27	774·52	200·30	871·33	225·34	968·14	250·38	30
33	580·75	150·73	677·55	175·86	774·34	200·98	871·13	226·10	967·93	251·22	27
36	580·62	151·24	677·39	176·45	774·17	201·66	870·94	226·86	967·71	252·07	24
39	580·49	151·75	677·24	177·04	773·99	202·33	870·74	227·62	967·49	252·91	21
42	580·36	152·25	677·09	177·63	773·81	203·01	870·54	228·38	967·27	253·76	18
45	580·23	152·76	676·93	178·22	773·64	203·68	870·34	229·14	967·04	254·60	15
48	580·09	153·27	676·77	178·81	773·46	204·36	870·14	229·90	966·82	255·45	12
51	579·96	153·77	676·62	179·40	773·28	205·03	869·94	230·66	966·60	256·29	9
54	579·82	154·28	676·46	179·99	773·10	205·71	869·74	231·43	966·37	257·13	6
57	579·69	154·78	676·30	180·58	772·92	206·38	869·54	232·19	966·15	257·97	3
60	579·55	155·29	676·15	181·17	772·74	207·05	869·33	232·94	965·92	258·82	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

75 Deg.

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15 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	96·59	25·88	193·18	51·76	289·78	77·65	386·37	103·53	482·96	129·41	60
3	96·57	25·97	193·14	51·93	289·71	77·90	386·28	103·86	482·85	129·83	57
6	96·55	26·05	193·09	52·10	289·64	78·15	386·19	104·20	482·74	130·25	54
9	96·52	26·13	193·05	52·27	289·57	78·40	386·10	104·54	482·62	130·67	51
12	96·50	26·22	193·00	52·44	289·50	78·66	386·01	104·87	482·51	131·09	48
15	96·48	26·30	192·96	52·61	289·44	78·91	385·91	105·21	482·40	131·52	45
18	96·45	26·39	192·91	52·78	289·37	79·16	385·82	105·55	482·28	131·94	42
21	96·43	26·47	192·86	52·94	289·30	79·41	385·73	105·87	482·16	132·36	39
24	96·41	26·55	192·82	53·11	289·23	79·67	385·64	106·22	482·05	132·78	36
27	96·39	26·64	192·77	53·28	289·16	79·92	385·55	106·56	481·93	133·20	33
30	96·36	26·72	192·73	53·45	289·09	80·17	385·45	106·89	481·81	133·62	30
33	96·34	26·81	192·68	53·62	289·02	80·42	385·36	107·23	481·70	134·04	27
36	96·32	26·89	192·63	53·78	288·95	80·67	385·26	107·57	481·58	134·46	24
39	96·29	26·98	192·58	53·95	288·88	80·93	385·17	107·90	481·46	134·88	21
42	96·27	27·06	192·54	54·12	288·81	81·18	385·08	108·24	481·34	135·30	18
45	96·24	27·14	192·49	54·29	288·73	81·43	384·98	108·58	481·23	135·72	15
48	96·22	27·23	192·44	54·46	288·66	81·68	384·89	108·91	481·11	136·14	12
51	96·20	27·31	192·40	54·62	288·59	81·94	384·79	109·25	480·99	136·56	9
54	96·17	27·39	192·35	54·79	288·52	82·19	384·70	109·58	480·87	136·98	6
57	96·15	27·48	192·30	54·96	288·45	82·44	384·60	109·92	480·75	137·40	3
60	96·13	27·56	192·25	55·13	288·38	82·69	384·50	110·25	480·63	137·82	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

74 Deg.

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15 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	579·55	155·29	676·15	181·17	772·74	207·05	869·33	232·94	965·92	258·82	60
3	579·42	155·80	675·99	181·76	772·56	207·73	869·13	233·70	965·70	259·66	57
6	579·28	156·30	675·83	182·35	772·38	208·40	868·93	234·45	965·47	260·50	54
9	579·14	156·81	675·67	182·94	772·19	209·08	868·72	235·21	965·24	261·35	51
12	579·01	157·31	675·51	183·53	772·01	209·75	868·51	235·97	965·01	262·19	48
15	578·87	157·82	675·35	184·12	771·83	210·42	868·31	236·73	964·77	263·03	45
18	578·73	158·32	675·19	184·71	771·65	211·10	868·10	237·49	964·56	263·87	42
21	578·60	158·83	675·03	185·30	771·46	211·77	867·89	238·24	964·33	264·71	39
24	578·46	159·33	674·87	185·89	771·28	212·44	867·69	239·00	964·09	265·55	36
27	578·32	159·84	674·70	186·48	771·09	213·12	867·48	239·76	963·86	266·40	33
30	578·18	160·34	674·54	187·07	770·90	213·79	867·27	240·51	963·63	267·24	30
33	578·04	160·85	674·38	187·65	770·72	214·46	867·06	241·27	963·40	268·08	27
36	577·90	161·35	674·21	188·24	770·53	215·13	866·85	242·03	963·16	268·92	24
39	577·75	161·86	674·05	188·83	770·34	215·81	866·63	242·78	962·93	269·76	21
42	577·61	162·36	673·88	189·42	770·15	216·48	866·42	243·54	962·69	270·60	18
45	577·47	162·86	673·72	190·01	769·96	217·15	866·21	244·30	962·45	271·44	15
48	577·33	163·37	673·55	190·60	769·77	217·82	866·00	245·05	962·22	272·28	12
51	577·19	163·87	673·38	191·19	769·58	218·50	865·78	245·81	961·98	273·12	9
54	577·04	164·37	673·22	191·77	769·39	219·17	865·57	246·56	961·74	273·96	6
57	576·90	164·88	673·05	192·36	769·20	219·84	865·35	247·32	961·50	274·80	3
60	576·76	165·38	672·88	192·95	769·01	220·51	865·14	248·07	961·26	275·64	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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16 Deg.

Minutes.	Dist. 100. Lat. Per.	Dist. 100. Dep. Base.	Dist. 200. Lat. Per.	Dist. 200. Dep. Base.	Dist. 300. Lat. Per.	Dist. 300. Dep. Base.	Dist. 400. Lat. Per.	Dist. 400. Dep. Base.	Dist. 500. Lat. Per.	Dist. 500. Dep. Base.	
0	96·13	27·56	192·25	55·13	288·38	82·69	384·50	110·25	480·63	137·82	60
3	96·10	27·65	192·20	55·29	288·30	82·94	384·41	110·59	480·51	138·24	57
6	96·08	27·73	192·15	55·46	288·23	83·19	384·31	110·92	480·39	138·66	54
9	96·05	27·81	192·11	55·63	288·16	83·44	384·21	111·26	480·27	139·08	51
12	96·03	27·90	192·06	55·80	288·09	83·72	384·12	111·60	480·15	139·49	48
15	96·00	27·98	192·01	55·97	288·01	83·97	384·02	111·93	480·03	139·91	45
18	95·98	28·07	191·96	56·13	287·94	84·20	383·92	112·27	479·90	140·33	42
21	95·95	28·15	191·91	56·30	287·87	84·45	383·82	112·60	479·78	140·75	39
24	95·93	28·23	191·86	56·47	287·79	84·70	383·73	112·94	479·66	141·17	36
27	95·91	28·32	191·81	56·63	287·72	84·95	383·63	113·27	479·53	141·59	33
30	95·88	28·40	191·76	56·80	287·65	85·20	383·53	113·61	479·41	142·01	30
33	95·86	28·48	191·71	56·97	287·57	85·45	383·43	113·94	479·28	142·43	27
36	95·83	28·57	191·66	57·14	287·50	85·71	383·33	114·27	479·16	142·84	24
39	95·81	28·65	191·61	57·30	287·42	85·96	383·23	114·61	479·03	143·26	21
42	95·78	28·74	191·56	57·47	287·35	86·21	383·13	114·94	478·91	143·68	18
45	95·76	28·82	191·51	57·64	287·27	86·46	383·03	115·28	478·78	144·10	15
48	95·73	28·90	191·46	57·81	287·20	86·71	382·93	115·61	478·66	144·51	12
51	95·71	28·99	191·41	57·97	287·12	86·96	382·83	115·95	478·53	144·93	9
54	95·68	29·07	191·36	58·14	287·04	87·21	382·72	116·28	478·40	145·35	6
57	95·65	29·15	191·31	58·31	286·97	87·46	382·62	116·62	478·28	145·77	3
60	95·63	29·24	191·26	58·47	286·89	87·71	382·52	116·95	478·15	146·18	0
	Base. Per.		Base. Per.		Base. Per.		Base. Per.		Base. Per.		Minutes.
	Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		Dep. Lat.		
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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16 Deg.

Minutes.	Dist. 600. Lat. Per.	Dist. 600. Dep. Base.	Dist. 700. Lat. Per.	Dist. 700. Dep. Base.	Dist. 800. Lat. Per.	Dist. 800. Dep. Base.	Dist. 900. Lat. Per.	Dist. 900. Dep. Base.	Dist. 1000. Lat. Per.	Dist. 1000. Dep. Base.	
0	576·76	165·38	672·88	192·95	769·01	220·51	865·14	248·07	961·26	275·64	60
3	576·61	165·88	672·71	193·53	768·82	221·18	864·92	248·83	961·02	276·48	57
6	576·47	166·39	672·54	194·12	768·62	221·85	864·70	249·58	960·78	277·31	54
9	576·32	166·89	672·37	194·71	768·43	222·52	864·48	250·34	960·53	278·15	51
12	576·18	167·39	672·20	195·29	768·23	223·19	864·27	251·09	960·29	278·99	48
15	576·03	167·90	672·03	195·88	768·04	223·86	864·05	251·84	960·05	279·83	45
18	575·88	168·40	671·86	196·47	767·84	224·53	863·83	252·60	959·80	280·67	42
21	575·74	168·90	671·69	197·05	767·65	225·20	863·61	253·35	959·56	281·50	39
24	575·59	169·40	671·52	197·64	767·45	225·87	863·39	254·11	959·31	282·34	36
27	575·44	169·91	671·35	198·22	767·25	226·54	863·16	254·86	959·07	283·18	33
30	575·29	170·41	671·17	198·81	767·05	227·21	862·94	255·61	958·82	284·01	30
33	575·14	170·91	671·00	199·40	766·85	227·88	862·71	256·38	958·57	284·85	27
36	574·99	171·41	670·82	199·98	766·66	228·55	862·49	257·12	958·32	285·69	24
39	574·84	171·91	670·65	200·57	766·46	229·22	862·27	257·87	958·07	286·52	21
42	574·69	172·42	670·47	201·15	766·26	229·89	862·04	258·62	957·82	287·36	18
45	574·54	172·92	670·30	201·74	766·05	230·56	861·81	259·37	957·57	288·20	15
48	574·39	173·42	670·12	202·32	765·85	231·23	861·59	260·13	957·32	289·03	12
51	574·24	173·92	669·95	202·91	765·65	231·89	861·36	260·88	957·07	289·87	9
54	574·09	174·42	669·77	203·49	765·45	232·56	861·13	261·63	956·81	290·70	6
57	573·93	174·92	669·59	204·08	765·25	233·23	860·90	262·38	956·56	291·54	3
60	573·78	175·42	669·41	204·66	765·04	233·90	860·68	263·13	956·30	292·37	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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17 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	95·63	29·24	191·26	58·47	286·89	87·71	382·52	116·95	478·15	146·18	60
3	95·60	29·32	191·21	58·64	286·81	87·96	382·42	117·28	478·02	146·60	57
6	95·58	29·40	191·16	58·81	286·74	88·21	382·32	117·62	477·89	147·02	54
9	95·55	29·49	191·11	58·97	286·66	88·46	382·21	117·95	477·77	147·44	51
12	95·53	29·57	191·05	59·14	286·58	88·71	382·11	118·28	477·64	147·85	48
15	95·50	29·65	191·00	59·31	286·50	88·96	382·01	118·62	477·54	148·27	45
18	95·47	29·74	190·95	59·47	286·43	89·21	381·90	118·95	477·38	148·69	42
21	95·45	29·82	190·90	59·64	286·35	89·46	381·80	119·28	477·25	149·10	39
24	95·42	29·90	190·85	59·81	286·27	89·71	381·70	119·62	477·12	149·52	36
27	95·40	29·99	190·80	59·97	286·19	89·96	381·59	119·95	476·99	149·94	33
30	95·37	30·07	190·74	60·14	286·11	90·21	381·49	120·28	476·86	150·35	30
33	95·34	30·15	190·69	60·31	286·03	90·46	381·38	120·62	476·73	150·77	27
36	95·32	30·24	190·64	60·47	285·96	90·71	381·27	120·95	476·59	151·18	24
39	95·29	30·32	190·58	60·64	285·88	90·96	381·17	121·28	476·46	151·60	21
42	95·26	30·40	190·53	60·81	285·80	91·21	381·06	121·61	476·33	152·02	18
45	95·24	30·49	190·48	60·97	285·72	91·46	380·96	121·94	476·20	152·43	15
48	95·21	30·57	190·43	61·14	285·64	91·71	380·85	122·27	476·06	152·85	12
51	95·18	30·65	190·37	61·30	285·56	91·96	380·74	122·61	475·93	153·26	9
54	95·16	30·73	190·32	61·47	285·48	92·21	380·64	122·94	475·80	153·68	6
57	95·13	30·82	190·26	61·64	285·40	92·45	380·53	123·27	475·66	154·09	3
60	95·10	30·90	190·21	61·80	285·32	92·70	380·42	123·61	475·53	154·51	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

72 Deg.

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17 Deg.

Minutes.	Dist. 600. Lat. Per.	Dist. 600. Dep. Base.	Dist. 700. Lat. Per.	Dist. 700. Dep. Base.	Dist. 800. Lat. Per.	Dist. 800. Dep. Base.	Dist. 900. Lat. Per.	Dist. 900. Dep. Base.	Dist. 1000. Lat. Per.	Dist. 1000. Dep. Base.	
0	573·78	175·42	669·41	204·66	765·04	233·90	860·68	263·13	956·30	292·37	60
3	573·63	175·92	669·23	205·24	764·84	234·56	860·44	263·88	956·05	293·20	57
6	573·47	176·42	669·05	205·83	764·63	235·23	860·21	264·64	955·79	294·04	54
9	573·32	176·92	668·87	206·41	764·43	235·90	859·98	265·39	955·53	294·87	51
12	573·16	177·42	668·69	207·00	764·22	236·56	859·75	266·14	955·28	295·71	48
15	573·01	177·92	668·51	207·58	764·01	237·23	859·52	266·89	955·02	296·54	45
18	572·85	178·42	668·33	208·16	763·81	237·90	859·28	267·64	954·76	297·37	42
21	572·70	178·92	668·15	208·74	763·60	238·56	859·05	268·39	954·50	298·21	39
24	572·54	179·42	667·97	209·33	763·39	239·23	858·82	269·14	954·24	299·04	36
27	572·39	179·92	667·78	209·91	763·18	239·90	858·58	269·88	953·98	299·87	33
30	572·23	180·42	667·60	210·49	762·98	240·56	858·34	270·63	953·72	300·70	30
33	572·07	180·92	667·42	211·08	762·76	241·23	858·11	271·38	953·45	301·53	27
36	571·91	181·42	667·23	211·66	762·55	241·90	857·87	272·13	953·19	302·37	24
39	571·75	181·92	667·05	212·24	762·34	242·56	857·63	272·88	952·92	303·20	21
42	571·60	182·42	666·86	212·82	762·13	243·22	857·39	273·63	952·66	304·03	18
45	571·44	182·92	666·68	213·40	761·92	243·89	857·15	274·38	952·39	304·86	15
48	571·28	183·42	666·49	213·99	761·70	244·55	856·91	275·13	952·13	305·69	12
51	571·12	183·92	666·30	214·57	761·49	245·22	856·67	275·87	951·86	306·53	9
54	570·95	184·41	666·11	215·15	761·27	245·88	856·43	276·62	951·59	307·36	6
57	570·79	184·91	665·93	215·73	761·06	246·55	856·19	277·37	951·32	308·19	3
60	570·63	185·41	665·74	216·31	760·84	247·21	855·95	278·11	951·05	309·02	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

72 Deg.

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18 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	l'er.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	95·10	30·90	190·21	61·80	285·32	92·71	380·42	123·61	475·53	154·51	60
3	95·08	30·98	190·16	61·97	285·23	92·95	380·31	123·94	475·39	154·92	57
6	95·05	31·07	190·10	62·13	285·15	93·20	380·21	124·27	475·26	155·34	54
9	95·02	31·15	190·05	62·30	285·07	93·45	380·10	124·60	475·12	155·75	51
12	95·00	31·23	189·99	62·47	284·99	93·70	379·99	124·93	474·98	156·17	48
15	94·97	31·32	189·94	62·63	284·91	93·95	379·88	125·26	474·85	156·58	45
18	94·94	31·40	189·88	62·80	284·83	94·20	379·77	125·60	474·71	156·99	42
21	94·91	31·48	189·83	62·96	284·74	94·44	379·66	125·93	474·57	157·41	39
24	94·88	31·56	189·77	63·13	284·66	94·69	379·55	126·26	474·44	157·82	36
27	94·86	31·65	189·72	63·29	284·58	94·94	379·44	126·59	474·30	158·24	33
30	94·83	31·73	189·66	63·46	284·50	95·19	379·33	126·92	474·16	158·65	30
33	94·80	31·81	189·61	63·63	284·41	95·44	379·22	127·25	474·02	159·07	27
36	94·78	31·89	189·55	63·79	284·33	95·69	379·11	127·58	473·88	159·48	24
39	94·75	31·98	189·50	63·96	284·25	95·94	378·99	127·91	473·74	159·89	21
42	94·72	32·06	189·44	64·12	284·16	96·18	378·88	128·24	473·60	160·31	18
45	94·69	32·14	189·38	64·29	284·08	96·43	378·77	128·58	473·46	160·72	15
48	94·66	32·23	189·33	64·45	283·99	96·68	378·66	128·91	473·32	161·13	12
51	94·64	32·31	189·27	64·62	283·91	96·93	378·55	129·24	473·18	161·54	9
54	94·61	32·39	189·22	64·78	283·82	97·17	378·43	129·57	473·04	161·96	6
57	94·58	32·47	189·16	64·95	283·74	97·42	378·32	129·90	472·90	162·37	3
60	94·55	32·56	189·10	65·11	283·65	97·67	378·21	130·23	472·76	162·78	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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18 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	570·63	185·41	665·74	216·31	760·84	247·21	855·95	278·11	951·05	309·02	60
3	570·47	185·91	665·55	216·89	760·63	247·88	855·71	278·86	950·78	310·85	57
6	570·31	186·41	665·36	217·47	760·41	248·54	855·46	279·61	950·51	310·68	54
9	570·14	186·90	665·17	218·05	760·19	249·20	855·22	280·36	950·24	311·50	51
12	569·98	187·40	664·98	218·63	759·98	249·87	854·97	281·10	949·97	312·33	48
15	569·82	187·90	664·79	219·21	759·76	250·53	854·73	281·85	949·70	313·16	45
18	569·65	188·40	664·60	219·79	759·54	251·19	854·48	282·59	949·42	313·99	42
21	569·49	188·89	664·40	220·37	759·32	251·86	854·23	283·34	949·15	314·82	39
24	569·32	189·39	664·21	220·95	759·10	252·52	853·99	284·08	948·87	315·65	36
27	569·16	189·89	664·02	221·53	758·88	253·18	853·74	284·83	948·60	316·48	33
30	568·99	190·38	663·83	222·11	758·66	253·84	853·49	285·57	948·32	317·30	30
33	568·83	190·88	663·63	222·69	758·44	254·50	853·24	286·32	948·04	318·13	27
36	568·66	191·38	663·44	223·27	758·22	255·17	852·99	287·06	947·77	318·96	24
39	568·49	191·87	663·24	223·85	757·99	255·83	852·74	287·81	947·49	319·78	21
42	568·32	192·37	663·05	224·43	757·77	256·49	852·49	288·55	947·21	320·61	18
45	568·16	192·86	662·85	225·01	757·54	257·15	852·24	289·29	946·93	321·44	15
48	567·99	193·36	662·65	225·58	757·32	257·81	851·98	290·04	946·65	322·26	12
51	567·82	193·85	662·46	226·16	757·09	258·47	851·73	290·78	946·37	323·09	9
54	567·65	194·35	662·26	226·74	756·87	259·13	851·48	291·52	946·08	323·92	6
57	567·48	194·84	662·06	227·32	756·64	259·79	851·22	292·27	945·80	324·74	3
60	567·31	195·34	661·86	227·90	756·41	260·45	850·97	293·01	945·52	325·57	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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19 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	94·55	32·56	189·10	65·11	283·65	97·67	378·21	130·23	472·76	162·78	60
3	94·52	32·64	189·05	65·28	283·57	97·92	378·09	130·56	472·62	163·20	57
6	94·49	32·72	188·99	65·44	283·48	98·16	377·98	130·89	472·47	163·61	54
9	94·47	32·80	188·93	65·61	283·40	98·41	377·86	131·22	472·33	164·02	51
12	94·44	32·89	188·87	65·77	283·31	98·66	377·75	131·55	472·19	164·43	48
15	94·41	32·97	188·82	65·94	283·23	98·91	377·63	131·88	472·04	164·84	45
18	94·38	33·05	188·76	66·10	283·14	99·15	377·52	132·20	471·90	165·26	42
21	94·35	33·14	188·70	66·27	283·05	99·40	377·40	132·53	471·75	165·67	39
24	94·32	33·22	188·64	66·43	282·97	99·65	377·29	132·86	471·61	166·08	36
27	94·29	33·30	188·59	66·60	282·88	99·89	377·17	133·19	471·46	166·49	33
30	94·26	33·38	188·53	66·76	282·79	100·14	377·06	133·52	471·32	166·90	30
33	94·23	33·46	188·47	66·93	282·70	100·39	376·94	133·85	471·17	167·31	27
36	94·20	33·54	188·41	67·09	282·62	100·63	376·82	134·18	471·03	167·72	24
39	94·18	33·63	188·35	67·25	282·53	100·88	376·70	134·51	470·88	168·14	21
42	94·15	33·71	188·29	67·42	282·44	101·13	376·59	134·84	470·73	168·55	18
45	94·12	33·79	188·23	67·58	282·35	101·37	376·47	135·17	470·59	168·96	15
48	94·09	33·87	188·18	67·75	282·26	101·62	376·35	135·49	470·44	169·37	12
51	94·06	33·95	188·12	67·91	282·17	101·87	376·23	135·82	470·29	169·78	9
54	94·03	34·04	188·06	68·07	282·09	102·11	376·11	136·15	470·14	170·19	6
57	94·00	34·12	188·00	68·24	282·00	102·36	375·99	136·48	469·99	170·60	3
60	93·97	34·20	187·94	68·40	281·91	102·60	375·87	136·81	469·84	171·01	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Minutes.
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	567·31	195·34	661·86	227·90	756·41	260·45	850·97	293·01	945·52	325·57	60
3	567·14	195·83	661·66	228·47	756·19	261·11	850·71	293·75	945·23	326·39	57
6	566·97	196·33	661·46	229·05	755·96	261·77	850·45	294·49	944·95	327·22	54
9	566·80	196·83	661·26	229·63	755·73	262·43	850·20	295·24	944·66	328·04	51
12	566·62	197·32	661·06	230·21	755·50	263·09	849·94	295·98	944·38	328·87	48
15	566·45	197·81	660·86	230·78	755·27	263·75	849·68	296·72	944·09	329·69	45
18	566·28	198·31	660·66	231·36	755·04	264·41	849·42	297·46	943·80	330·51	42
21	566·11	198·80	660·46	231·94	754·81	265·07	849·16	298·20	943·51	331·34	39
24	565·93	199·30	660·25	232·51	754·58	265·73	848·90	298·94	943·22	332·16	36
27	565·76	199·79	660·05	233·09	754·34	266·39	848·64	299·69	942·93	332·98	33
30	565·58	200·28	659·85	233·66	754·11	267·04	848·38	300·43	942·64	333·80	30
33	565·41	200·78	659·64	234·24	753·88	267·70	848·11	301·17	942·35	334·63	27
36	565·23	201·27	659·44	234·81	753·64	268·36	847·85	301·91	942·06	335·45	24
39	565·06	201·76	659·23	235·39	753·41	269·02	847·59	302·65	941·76	336·27	21
42	564·88	202·26	659·03	235·97	753·17	269·67	847·32	303·39	941·47	337·09	18
45	564·70	202·75	658·82	236·54	752·94	270·33	847·06	304·13	941·17	337·91	15
48	564·53	203·24	658·62	237·11	752·70	270·99	846·79	304·86	940·88	338·74	12
51	564·35	203·73	658·41	237·69	752·47	271·65	846·53	305·60	940·58	339·56	9
54	564·17	204·23	658·20	238·26	752·23	272·30	846·26	306·34	940·29	340·38	6
57	563·99	204·72	657·99	238·84	751·99	272·96	845·99	307·08	939·99	341·20	3
60	563·81	205·21	657·78	239·41	751·75	273·61	845·72	307·82	939·69	342·02	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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20 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	93·97	34·20	187·94	68·40	281·91	102·60	375·87	136·81	469·84	171·01	60
3	93·94	34·28	187·88	68·57	281·82	102·85	375·76	137·13	469·70	171·42	57
6	93·91	34·36	187·82	68·73	281·73	103·10	375·64	137·46	469·55	171·83	54
9	93·88	34·45	187·76	68·89	281·64	103·34	375·52	137·79	469·40	172·24	51
12	93·85	34·53	187·70	69·06	281·55	103·59	375·40	138·12	469·25	172·65	48
15	93·82	34·61	187·64	69·22	281·46	103·84	375·28	138·45	469·10	173·06	45
18	93·79	34·69	187·58	69·39	281·37	104·08	375·15	138·77	468·94	173·47	42
21	93·76	34·77	187·52	69·55	281·27	104·33	375·03	139·10	468·79	173·88	39
24	93·73	34·86	187·46	69·71	281·18	104·57	374·91	139·43	468·64	174·28	36
27	93·70	34·94	187·39	69·88	281·09	104·82	374·79	139·75	468·49	174·69	33
30	93·67	35·02	187·33	70·04	281·00	105·06	374·67	140·08	468·34	175·10	30
33	93·64	35·10	187·27	70·20	280·91	105·31	374·55	140·41	468·18	175·51	27
36	93·61	35·18	187·21	70·37	280·82	105·55	374·42	140·74	468·03	175·92	24
39	93·57	35·26	187·15	70·53	280·72	105·80	374·30	141·06	467·87	176·33	21
42	93·54	35·35	187·09	70·69	280·63	106·04	374·18	141·39	467·72	176·74	18
45	93·51	35·43	187·03	70·86	280·54	106·29	374·05	141·72	467·57	177·15	15
48	93·48	35·51	186·96	71·02	280·45	106·53	373·93	142·04	467·41	177·55	12
51	93·45	35·59	186·90	71·18	280·35	106·78	373·80	142·37	467·26	177·96	9
54	93·42	35·67	186·84	71·35	280·26	107·02	373·68	142·69	467·10	178·37	6
57	93·39	35·75	186·78	71·51	280·17	107·27	373·56	143·02	466·94	178·77	3
60	93·36	35·84	186·71	71·67	280·07	107·51	373·43	143·35	466·79	179·18	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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20 Deg.

Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	563·81	205·21	657·78	239·41	751·75	273·61	845·72	307·82	939·69	342·02	60
3	563·63	205·70	657·57	239·99	751·51	274·27	845·45	308·55	939·39	342·84	57
6	563·45	206·19	657·36	240·56	751·27	274·93	845·19	309·29	939·09	343·66	54
9	563·28	206·69	657·15	241·13	751·03	275·58	844·92	310·03	938·79	344·48	51
12	563·10	207·18	656·94	241·71	750·79	276·24	844·64	310·77	938·49	345·30	48
15	562·91	207·67	656·73	242·28	750·55	276·89	844·37	311·50	938·19	346·12	45
18	562·73	208·16	656·52	242·85	750·31	277·55	844·10	312·24	937·89	346·93	42
21	562·55	208·65	656·31	243·43	750·07	278·20	843·83	312·98	937·59	347·75	39
24	562·37	209·14	656·10	244·00	749·83	278·86	843·55	313·71	937·28	348·57	36
27	562·18	209·63	655·88	244·57	749·58	279·51	843·28	314·45	936·98	349·39	33
30	562·00	210·12	655·67	245·14	749·34	280·16	843·00	315·19	936·67	350·21	30
33	561·82	210·61	655·45	245·72	749·09	280·82	842·73	315·92	936·37	351·02	27
36	561·64	211·10	655·24	246·29	748·85	281·47	842·45	316·66	936·06	351·84	24
39	561·45	211·59	655·02	246·86	748·60	282·13	842·17	317·39	935·75	352·66	21
42	561·26	212·08	654·81	247·43	748·35	282·78	841·90	318·13	935·44	353·47	18
45	561·08	212·57	654·59	248·00	748·11	283·43	841·62	318·86	935·13	354·29	15
48	560·89	213·06	654·38	248·57	747·86	284·08	841·34	319·60	934·82	355·11	12
51	560·71	213·55	654·16	249·14	747·61	284·74	841·06	320·33	934·51	355·92	9
54	560·52	214·04	653·94	249·72	747·36	285·39	840·78	321·06	934·20	356·74	6
57	560·33	214·53	653·72	250·29	747·11	286·04	840·50	321·80	933·89	357·55	3
60	560·15	215·02	653·50	250·86	746·86	286·69	840·22	322·53	933·58	358·37	0
	Base	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Minutes.
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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21 Deg.

Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	93·36	35·84	186·71	71·67	280·07	107·51	373·43	143·34	466·79	179·18	60
3	93·32	35·91	186·65	71·83	279·98	107·75	373·31	143·67	466·63	179·59	57
6	93·29	35·99	186·59	71·99	279·88	107·99	373·18	143·99	466·47	179·99	54
9	93·26	36·08	186·53	72·15	279·79	108·23	373·06	144·32	466·32	180·40	51
12	93·23	36·16	186·46	72·32	279·69	108·48	372·93	144·65	466·16	180·81	48
15	93·20	36·24	186·40	72·48	279·60	108·72	372·80	144·97	466·00	181·22	45
18	93·16	36·32	186·33	72·65	279·50	108·97	372·67	145·30	465·84	181·62	42
21	93·13	36·40	186·27	72·81	279·41	109·21	372·55	145·63	465·68	182·03	39
24	93·10	36·48	186·21	72·97	279·31	109·46	372·42	145·95	465·52	182·43	36
27	93·07	36·56	186·15	73·13	279·22	109·70	372·29	146·27	465·36	182·84	33
30	93·04	36·65	186·08	73·30	279·12	109·94	372·16	146·60	465·20	183·25	30
33	93·00	36·73	186·02	73·46	279·03	110·19	372·04	146·92	465·04	183·65	27
36	92·97	36·81	185·95	73·62	278·93	110·43	371·91	147·24	464·88	184·06	24
39	92·94	36·89	185·89	73·78	278·83	110·67	371·78	147·57	464·72	184·47	21
42	92·91	36·97	185·82	73·94	278·73	110·92	371·65	147·89	464·56	184·87	18
45	92·88	37·05	185·76	74·10	278·64	111·16	371·52	148·22	464·40	185·28	15
48	92·84	37·13	185·69	74·27	278·54	111·41	371·39	148·54	464·24	185·68	12
51	92·81	37·21	185·63	74·43	278·45	111·65	371·26	148·87	464·08	186·09	9
54	92·78	37·29	185·56	74·59	278·35	111·89	371·13	149·19	463·92	186·49	6
57	92·75	37·37	185·50	74·75	278·25	112·14	371·00	149·52	463·76	186·90	3
60	92·71	37·46	185·43	74·92	278·15	112·38	370·87	149·84	463·59	187·30	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	560·14	215·02	653·50	250·85	746·86	286·69	840·22	322·53	933·58	358·37	60
3	559·96	215·50	653·28	251·42	746·61	287·34	839·94	323·26	933·26	359·18	57
6	559·77	215·99	653·06	251·99	746·36	287·99	839·66	323·99	932·95	359·99	54
9	559·58	216·48	652·84	252·56	746·11	288·64	839·38	324·72	932·64	360·81	51
12	559·39	216·97	652·62	253·13	745·86	289·29	839·09	325·46	932·32	361·62	48
15	559·20	217·46	652·40	253·70	745·61	289·94	838·81	326·19	932·01	362·44	45
18	559·01	217·95	652·18	254·27	745·35	290·60	838·52	326·92	931·69	363·25	42
21	558·82	218·44	651·96	254·84	745·10	291·25	838·24	327·65	931·37	364·06	39
24	558·63	218·92	651·73	255·41	744·84	291·90	837·95	328·38	931·05	364·87	36
27	558·44	219·41	651·51	255·98	744·59	292·55	837·66	329·11	930·73	365·69	33
30	558·24	219·90	651·29	256·55	744·33	293·20	837·37	329·85	930·41	366·50	30
33	558·05	220·39	651·07	257·12	744·08	293·85	837·08	330·58	930·09	367·31	27
36	557·86	220·87	650·84	257·68	743·82	294·50	836·79	331·31	929·77	368·12	24
39	557·67	221·36	650·62	258·25	743·56	295·15	836·50	332·04	929·45	368·93	21
42	557·47	221·84	650·39	258·82	743·30	295·79	836·21	332·77	929·13	369·74	18
45	557·28	222·33	650·17	259·39	743·04	296·44	835·92	333·50	928·81	370·55	15
48	557·09	222·82	649·94	259·95	742·78	297·09	835·63	334·23	928·48	371·36	12
51	556·90	223·31	649·71	260·52	742·52	297·74	835·34	334·96	928·16	372·17	9
54	556·70	223·79	649·48	261·09	742·26	298·39	835·05	335·68	927·83	372·98	6
57	556·50	224·28	649·25	261·66	742·00	299·04	834·75	336·41	927·51	373·79	3
60	556·30	224·76	649·02	262·22	741·74	299·68	834·46	337·14	927·18	374·60	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	92·71	37·46	185·43	74·92	278·15	112·38	370·87	149·84	463·59	187·30	60
3	92·68	37·54	185·37	75·08	278·05	112·62	370·74	150·16	463·43	187·70	57
6	92·65	37·62	185·30	75·24	277·95	112·86	370·61	150·48	463·26	188·11	54
9	92·62	37·70	185·24	75·40	277·86	113·10	370·48	150·81	463·10	188·51	51
12	92·58	37·78	185·17	75·56	277·76	113·35	370·34	151·13	462·93	188·92	48
15	92·55	37·86	185·11	75·72	277·66	113·59	370·21	151·45	462·77	189·32	45
18	92·52	37·94	185·04	75·88	277·56	113·83	370·08	151·78	462·60	189·72	42
21	92·48	38·02	184·97	76·04	277·46	114·07	369·95	152·10	462·44	190·13	39
24	92·45	38·10	184·90	76·21	277·36	114·32	369·81	152·42	462·27	190·53	36
27	92·42	38·18	184·84	76·37	277·26	114·56	369·68	152·74	462·10	190·93	33
30	92·38	38·26	184·77	76·53	277·16	114·80	369·55	153·07	461·93	191·34	30
33	92·35	38·34	184·71	76·69	277·06	115·04	369·42	153·39	461·77	191·74	27
36	92·32	38·42	184·64	76·85	276·96	115·29	369·28	153·71	461·60	192·14	24
39	92·28	38·50	184·57	77·01	276·86	115·53	369·15	154·03	461·44	192·54	21
42	92·25	38·59	184·50	77·18	276·76	115·77	369·01	154·36	461·27	192·95	18
45	92·22	38·67	184·44	77·34	276·66	116·01	368·88	154·68	461·10	193·35	15
48	92·18	38·75	184·37	77·50	276·56	116·25	368·74	155·00	460·93	193·75	12
51	92·15	38·83	184·30	77·66	276·45	116·49	368·61	155·32	460·76	194·15	9
54	92·11	38·91	184·23	77·82	276·35	116·73	368·47	155·64	460·59	194·56	6
57	92·08	38·99	184·17	77·98	276·25	116·97	368·34	155·96	460·42	194·96	3
60	92·05	39·07	184·10	78·14	276·15	117·21	368·20	156·29	460·25	195·36	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	556·30	224·76	649·02	262·22	741·74	299·68	834·46	337·14	927·18	374·60	60
3	556·11	225·24	648·79	262·79	741·48	300·33	834·17	337·87	926·85	375·41	57
6	555·91	225·73	648·56	263·35	741·22	300·97	833·87	338·60	926·52	376·22	54
9	555·72	226·21	648·33	263·92	740·96	301·62	833·58	339·33	926·19	377·03	51
12	555·52	226·70	648·10	264·48	740·69	302·27	833·28	340·05	925·86	377·84	48
15	555·32	227·18	647·87	265·05	740·43	302·92	832·99	340·78	925·53	378·64	45
18	555·12	227·67	647·64	265·61	740·16	303·56	832·69	341·51	925·20	379·45	42
21	554·92	228·15	647·41	266·18	739·90	304·21	832·39	342·24	924·87	380·26	39
24	554·72	228·64	647·18	266·74	739·63	304·85	832·09	342·96	924·54	381·07	36
27	554·52	229·12	646·95	267·31	739·37	305·50	831·79	343·69	924·21	381·88	33
30	554·32	229·61	646·71	267·87	739·10	306·14	831·49	344·41	923·87	382·68	30
33	554·12	230·09	646·48	268·44	738·83	306·79	831·19	345·14	923·54	383·48	27
36	553·92	230·57	646·24	269·00	738·56	307·43	830·89	345·86	923·20	384·28	24
39	553·72	231·06	646·01	269·57	738·30	308·08	830·59	346·59	922·87	385·09	21
42	553·52	231·54	645·77	270·13	738·08	308·72	830·28	347·31	922·53	385·90	18
45	553·32	232·03	645·54	270·70	737·76	309·37	829·98	348·04	922·20	386·70	15
48	553·11	232·51	645·30	271·26	737·49	310·01	829·67	348·76	921·86	387·51	12
51	552·91	233·00	645·06	271·82	737·22	310·66	829·37	349·49	921·52	388·31	9
54	552·71	233·47	644·82	272·38	736·94	311·30	829·06	350·21	921·18	389·12	6
57	552·51	233·95	644·59	272·94	736·67	311·94	828·76	350·93	920·84	389·92	3
60	552·30	234·43	644·35	273·51	736·40	312·58	828·45	351·65	920·50	390·73	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	92·05	39·07	184·10	78·14	276·15	117·21	368·20	156·29	460·25	195·36	60
3	92·01	39·15	184·03	78·30	276·05	117·45	368·06	156·61	460·08	195·76	57
6	91·98	39·23	183·96	78·46	275·94	117·70	367·92	156·93	459·91	196·16	54
9	91·94	39·31	183·89	78·62	275·84	117·94	367·79	157·25	459·74	196·56	51
12	91·91	39·39	183·82	78·78	275·74	118·18	367·65	157·57	459·56	196·97	48
15	91·87	39·47	183·75	78·94	275·64	118·42	367·51	157·89	459·39	197·37	45
18	91·84	39·55	183·68	79·10	275·53	118·66	367·37	158·21	459·22	197·77	42
21	91·81	39·63	183·62	79·26	275·43	118·90	367·24	158·53	459·05	198·17	39
24	91·77	39·71	183·55	79·42	275·32	119·14	367·10	158·85	458·87	198·57	36
27	91·74	39·79	183·48	79·58	275·22	119·38	366·96	159·17	458·70	198·97	33
30	91·70	39·87	183·41	79·74	275·11	119·62	366·82	159·49	458·53	199·37	30
33	91·67	39·95	183·34	79·90	275·01	119·86	366·68	159·81	458·36	199·77	27
36	91·63	40·03	183·27	80·06	274·90	120·10	366·54	160·13	458·18	200·17	24
39	91·60	40·11	183·20	80·22	274·79	120·34	366·40	160·45	458·01	200·57	21
42	91·56	40·19	183·13	80·38	274·69	120·58	366·26	160·77	457·83	200·97	18
45	91·53	40·27	183·06	80·54	274·58	120·82	366·12	161·09	457·66	201·37	15
48	91·49	40·35	182·99	80·70	274·48	121·06	365·98	161·41	457·48	201·77	12
51	91·46	40·43	182·92	80·86	274·37	121·30	365·84	161·73	457·30	202·17	9
54	91·42	40·51	182·85	81·02	274·27	121·54	365·70	162·05	457·12	202·57	6
57	91·39	40·59	182·78	81·18	274·16	121·78	365·56	162·37	456·95	202·97	3
60	91·35	40·67	182·70	81·34	274·06	122·02	365·42	162·69	456·77	203·36	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	552·30	234·43	644·35	273·51	736·40	312·58	828·45	351·65	920·50	390·73	60
3	552·10	234·91	644·11	274·07	736·13	313·22	828·15	352·37	920·16	391·53	57
6	551·89	235·40	643·87	274·63	735·85	313·86	827·84	353·10	919·82	392·33	54
9	551·68	235·88	643·63	275·19	735·58	314·50	827·53	353·82	919·48	393·14	51
12	551·47	236·36	643·39	275·75	735·30	315·15	827·22	354·54	919·13	393·94	48
15	551·27	236·84	643·15	276·31	735·03	315·79	826·91	355·26	918·79	394·74	45
18	551·06	237·32	642·91	276·88	734·75	316·43	826·60	355·99	918·44	395·54	42
21	550·86	237·80	642·67	277·44	734·48	317·07	826·29	356·71	918·10	396·34	39
24	550·65	238·28	642·42	278·00	734·20	317·71	825·98	357·43	917·75	397·14	36
27	550·44	238·76	642·18	278·56	733·92	318·35	825·67	358·15	917·40	397·94	33
30	550·23	239·24	641·93	279·12	733·64	318·99	825·35	358·87	917·05	398·74	30
33	550·02	239·72	641·69	279·68	733·36	319·63	825·04	359·59	916·71	399·54	27
36	549·81	240·20	641·45	280·24	733·08	320·27	824·72	360·31	916·36	400·34	24
39	549·60	240·68	641·21	280·80	732·80	320·91	824·41	361·03	916·01	401·14	21
42	549·39	241·16	640·96	281·36	732·52	321·55	824·09	361·75	915·66	401·94	18
45	549·18	241·64	640·72	281·92	732·24	322·19	823·78	362·47	915·31	402·74	15
48	548·97	242·12	640·47	282·48	731·96	322·83	823·46	363·19	914·95	403·54	12
51	548·76	242·60	640·22	283·04	731·68	323·47	823·14	363·91	914·60	404·34	9
54	548·55	243·08	639·97	283·60	731·40	324·11	822·82	364·62	914·25	405·14	6
57	548·34	243·56	639·73	284·16	731·12	324·75	822·51	365·34	913·90	405·94	3
60	548·12	244·04	639·48	284·71	730·83	325·38	822·19	366·06	913·54	406·73	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	91·35	40·67	182·70	81·34	274·06	122·02	365·42	162·69	456·77	203·36	60
3	91·31	40·75	182·63	81·50	273·95	122·26	365·28	163·01	456·59	203·76	57
6	91·28	40·82	182·56	81·66	273·84	122·49	365·13	163·33	456·41	204·16	54
9	91·24	40·91	182·49	81·82	273·74	122·73	364·99	163·65	456·24	204·56	51
12	91·21	40·99	182·42	81·98	273·63	122·97	364·84	163·96	456·06	204·96	48
15	91·17	41·07	182·35	82·14	273·53	123·21	364·70	164·28	455·88	205·36	45
18	91·14	41·15	182·28	82·30	273·42	123·45	364·56	164·60	455·70	205·75	42
21	91·10	41·23	182·21	82·46	273·31	123·69	364·42	164·92	455·52	206·15	39
24	91·06	41·31	182·13	82·62	273·20	123·93	364·27	165·24	455·34	206·55	36
27	91·03	41·39	182·06	82·78	273·09	124·17	364·13	165·56	455·16	206·95	33
30	90·99	41·46	181·99	82·93	272·98	124·40	363·98	165·87	454·98	207·34	30
33	90·95	41·54	181·92	83·09	272·88	124·64	363·84	166·19	454·80	207·74	27
36	90·92	41·62	181·84	83·25	272·77	124·88	363·69	166·51	454·61	208·14	24
39	90·88	41·70	181·77	83·41	272·66	125·12	363·55	166·83	454·43	208·54	21
42	90·85	41·78	181·70	83·57	272·55	125·36	363·41	167·14	454·25	208·93	18
45	90·81	41·86	181·63	83·73	272·44	125·60	363·26	167·46	454·07	209·33	15
48	90·77	41·94	181·55	83·89	272·33	125·83	363·11	167·78	453·88	209·72	12
51	90·74	42·02	181·48	84·05	272·22	126·07	362·96	168·10	453·70	210·12	9
54	90·70	42·10	181·40	84·20	272·11	126·31	362·82	168·41	453·52	210·51	6
57	90·66	42·18	181·33	84·36	272·00	126·55	362·67	168·73	453·34	210·91	3
60	90·63	42·26	181·26	84·52	271·89	126·78	362·52	169·04	453·15	211·30	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	548·12	244·04	639·48	284·71	730·83	325·38	822·19	366·06	913·54	406·73	60
3	547·91	244·52	639·23	285·27	730·55	326·02	821·87	366·78	913·19	407·53	57
6	547·70	244·99	638·98	285·83	730·26	326·66	821·54	367·49	912·83	408·33	54
9	547·49	245·47	638·73	286·39	729·98	327·30	821·22	368·21	912·48	409·13	51
12	547·27	245·95	638·48	286·94	729·69	327·93	820·90	368·93	912·12	409·92	48
15	547·06	246·43	638·23	287·50	729·41	328·57	820·58	369·65	911·76	410·72	45
18	546·84	246·90	637·98	288·06	729·12	329·21	820·26	370·36	911·40	411·51	42
21	546·62	247·38	637·73	288·62	728·83	329·85	819·94	371·08	911·04	412·31	39
24	546·40	247·86	637·47	289·17	728·54	330·48	819·61	371·79	910·67	413·10	36
27	546·19	248·34	637·22	289·73	728·25	331·12	819·29	372·51	910·31	413·90	33
30	545·97	248·81	636·97	290·28	727·96	331·75	818·96	373·22	909·95	414·69	30
33	545·76	249·29	636·72	290·84	727·67	332·39	818·64	373·94	909·59	415·49	27
36	545·54	249·76	636·46	291·39	727·38	333·02	818·31	374·65	909·23	416·28	24
39	545·32	250·24	636·21	291·95	727·09	333·66	817·98	375·37	908·87	417·07	21
42	545·10	250·72	635·95	292·50	726·80	334·29	817·65	376·08	908·50	417·86	18
45	544·88	251·20	635·70	293·06	726·51	334·93	817·33	376·79	908·14	418·66	15
48	544·66	251·67	635·44	293·61	726·22	335·56	817·00	377·50	907·77	419·45	12
51	544·44	252·15	635·19	294·17	725·93	336·19	816·67	378·22	907·41	420·24	9
54	544·22	252·62	634·93	294·72	725·63	336·82	816·34	378·93	907·04	421·03	6
57	544·00	253·10	634·67	295·28	725·34	337·46	816·01	379·64	906·67	421·82	3
60	543·78	253·57	634·41	295·83	725·04	338·09	815·67	380·35	906·30	422·61	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	90 63	42·26	181·26	84·52	271·89	126·78	362·52	169·04	453·15	211·30	60
3	90·59	42·34	181·19	84·68	271·78	127·02	362·37	169·36	452·97	211·70	57
6	90·55	42·42	181·11	84·84	271·67	127·25	362·22	169·68	452·78	212·10	54
9	90·51	42·49	181·04	84·99	271·56	127·49	362·08	170·00	452·60	212·49	51
12	90·48	42·57	180·96	85·15	271·44	127·73	361·93	170·31	452·41	212·88	48
15	90·44	42·65	180·89	85·31	271·33	127·97	361·78	170·63	452·23	213·28	45
18	90·40	42·73	180·81	85·47	271·22	128·20	361·63	170·94	452·04	213·67	42
21	90·37	42·81	180·74	85·63	271·11	128·44	361·48	171·26	451·85	214·07	39
24	90·33	42·89	180·66	85·78	271·00	128·68	361·33	171·57	451·66	214·46	36
27	90·29	42·97	180·59	85·94	270·89	128·92	361·18	171·89	451·48	214·86	33
30	90·25	43·05	180·51	86·10	270·77	129·15	361·03	172·20	451·29	215·25	30
33	90·22	43·13	180·44	86·26	270·66	129·39	360·88	172·52	451·10	215·65	27
36	90·18	43·20	180·36	86·41	270·55	129·62	360·73	172·83	450·91	216·04	24
39	90·14	43·28	180·29	86·57	270·44	129·86	360·58	173·15	450·72	216·44	21
42	90·10	43·36	180·21	86·73	270·32	130·09	360·43	173·46	450·53	216·83	18
45	90·06	43·44	180·14	86·89	270·21	130·33	360·28	173·78	450·34	217·22	15
48	90·03	43·52	180·06	87·04	270·09	130·56	360·12	174·09	450·15	217·61	12
51	89·99	43·59	179·99	87·20	269·98	130·80	359·97	174·41	449·96	218·01	9
54	89·95	43·67	179·91	87·36	269·86	131·04	359·82	174·72	449·77	218·40	6
57	89·91	43·75	179·83	87·52	269·75	131·27	359·67	175·03	449·58	218·79	3
60	89·87	43·83	179·75	87·67	269·63	131·51	359·51	175·34	449·39	219·18	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	543·78	253·57	634·41	295·83	725·04	338·09	815·67	380·35	906·30	422·61	60
3	543·56	254·04	634·15	296·38	724·75	338·73	815·34	381·06	905·93	423·40	57
6	543·34	254·51	633·89	296·94	724·45	339·36	815·01	381·78	905·56	424·20	54
9	543·12	254·99	633·63	297·49	724·16	340·00	814·68	382·49	905·19	424·99	51
12	542·89	255·46	633·37	298·04	723·86	340·63	814·34	383·20	904·82	425·78	48
15	542·67	255·94	633·11	298·60	723·56	341·26	814·01	383·91	904·45	426·57	45
18	542·44	256·41	632·85	299·15	723·26	341·89	813·67	384·62	904·08	427·35	42
21	542·22	256·89	632·59	299·70	722·96	342·52	813·34	385·33	903·71	428·14	39
24	542·00	257·36	632·33	300·25	722·66	343·15	813·00	386·04	903·33	428·93	36
27	541·78	257·83	632·07	300·80	722·36	343·78	812·66	386·75	902·96	429·72	33
30	541·55	258·30	631·81	301·35	722·06	344·40	812·32	387·46	902·58	430·51	30
33	541·32	258·77	631·55	301·90	721·76	345·03	811·98	388·17	902·21	431·30	27
36	541·09	259·25	631·28	302·45	721·46	345·66	811·64	388·87	901·83	432·08	24
39	540·87	259·72	631·02	303·00	721·16	346·29	811·30	389·58	901·45	432·87	21
42	540·64	260·19	630·75	303·56	720·86	346·92	810·96	390·29	901·07	433·65	18
45	540·42	260·67	630·49	304·11	720·56	347·55	810·62	391·00	900·69	434·44	15
48	540·19	261·14	630·22	304·66	720·25	348·18	810·28	391·70	900·31	435·23	12
51	539·96	261·61	629·96	305·21	719·95	348·81	809·94	392·41	899·93	435·92	9
54	539·73	262·08	629·69	305·76	719·64	349·44	809·60	393·12	899·55	436·80	6
57	539·50	262·55	629·42	306·31	719·34	350·07	809·26	393·83	899·17	437·59	3
60	539·27	263·02	629·15	306·86	719·03	350·69	808·91	394·53	898·79	438·37	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	89·87	43·83	179·75	87·67	269·63	131·51	359·51	175·34	449·39	219·18	60
3	89·84	43·91	179·68	87·83	269·52	131·75	359·36	175·65	449·20	219·57	57
6	89·80	43·99	179·60	87·98	269·40	131·98	359·21	175·97	449·01	219·96	54
9	89·76	44·07	179·53	88·14	269·29	132·22	359·06	176·28	448·82	220·35	51
12	89·72	44·15	179·45	88·30	269·17	132·45	358·90	176·60	448·62	220·75	48
15	89·68	44·22	179·37	88·46	269·06	132·69	358·75	176·91	448·43	221·14	45
18	89·64	44·30	179·29	88·61	268·94	132·92	358·59	177·22	448·24	221·53	42
21	89·61	44·38	179·22	88·77	268·83	133·16	358·44	177·53	448·05	221·92	39
24	89·57	44·46	179·14	88·92	268·71	133·39	358·28	177·85	447·85	222·31	36
27	89·53	44·54	179·06	89·08	268·59	133·63	358·13	178·16	447·66	222·70	33
30	89·49	44·61	178·98	89·23	268·47	133·86	357·97	178·47	447·46	223·09	30
33	89·45	44·69	178·91	89·39	268·36	134·09	357·82	178·78	447·27	223·48	27
36	89·41	44·77	178·83	89·55	268·24	134·32	357·66	179·10	447·07	223·87	24
39	89·37	44·85	178·75	89·71	268·13	134·56	357·50	179·41	446·88	224·26	21
42	89·33	44·93	178·67	89·86	268·01	134·79	357·34	179·72	446·68	224·65	18
45	89·29	45·00	178·59	90·02	267·89	135·03	357·19	180·03	446·49	225·04	15
48	89·25	45·08	178·51	90·17	267·77	135·26	357·03	180·35	446·29	225·43	12
51	89·21	45·16	178·43	90·33	267·65	135·50	356·87	180·66	446·10	225·82	9
54	89·17	45·24	178·35	90·48	267·53	135·73	356·71	180·97	445·90	226·21	6
57	89·14	45·32	178·28	90·64	267·42	135·96	356·56	181·28	445·70	226·60	3
60	89·10	45·39	178·20	90·79	267·30	136·19	356·40	181·59	445·50	226·99	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	539·27	263·02	629·15	306·86	719·03	350·69	808·91	394·53	898·79	438·37	60
3	539·04	263·49	628·88	307·41	718·73	351·32	808·57	395·24	898·41	439·15	57
6	538·81	263·96	628·61	307·95	718·42	351·95	808·22	395·94	898·02	439·93	54
9	538·58	264·43	628·34	308·50	718·11	352·58	807·88	396·65	897·64	440·71	51
12	538·35	264·90	628·07	309·05	717·80	353·20	807·53	397·35	897·25	441·50	48
15	538·12	265·37	627·81	309·60	717·49	353·83	807·18	398·06	896·87	442·28	45
18	537·89	265·84	627·54	310·14	717·18	354·45	806·83	398·76	896·48	443·06	42
21	537·66	266·31	627·27	310·69	716·87	355·08	806·49	399·47	896·10	443·84	39
24	537·42	266·78	626·99	311·24	716·56	355·70	806·14	400·17	895·71	444·63	36
27	537·19	267·25	626·72	311·79	716·25	356·33	805·79	400·88	895·32	445·41	33
30	536·96	267·71	626·45	312·33	715·94	356·95	805·44	401·58	894·93	446·19	30
33	536·73	268·18	626·18	312·88	715·63	357·58	805·09	402·28	894·54	446·97	27
36	536·49	268·65	625·90	313·43	715·32	358·20	804·73	402·98	894·15	447·75	24
39	536·26	269·12	625·63	313·97	715·01	358·83	804·38	403·68	893·76	448·53	21
42	536·02	269·59	625·36	314·52	714·69	359·45	804·03	404·38	893·37	449·31	18
45	535·79	270·06	625·09	315·07	714·38	360·08	803·68	405·08	892·98	450·09	15
48	535·55	270·52	624·81	315·61	714·06	360·70	803·32	405·78	892·58	450·87	12
51	535·31	270·99	624·53	316·16	713·75	361·32	802·97	406·48	892·19	451·65	9
54	535·07	271·46	624·25	316·70	713·43	361·94	802·61	407·19	891·79	452·43	6
57	534·84	271·93	623·98	317·25	713·12	362·57	802·26	407·89	891·40	453·21	3
60	534·60	272·39	623·70	317·79	712·80	363·19	801·90	408·59	891·00	453·99	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	89·10	45·39	178·20	90·79	267·30	136·19	356·40	181·59	445·50	226·99	60
3	89·06	45·47	178·12	90·94	267·18	136·42	356·24	181·90	445·30	227·38	57
6	89·02	45·55	178·04	91·10	267·06	136·66	356·08	182·21	445·10	227·77	54
9	88·98	45·63	177·96	91·25	266·94	136·89	355·92	182·52	444·90	228·16	51
12	88·94	45·70	177·88	91·41	266·82	137·12	355·76	182·83	444·70	228·54	48
15	88·90	45·78	177·80	91·57	266·70	137·35	355·60	183·14	444·50	228·93	45
18	88·86	45·86	177·72	91·73	266·58	137·59	355·44	183·46	444·30	229·32	42
21	88·82	45·94	177·64	91·88	266·46	137·82	355·28	183·77	444·10	229·71	39
24	88·78	46·01	177·56	92·04	266·34	138·06	355·12	184·08	443·90	230·10	36
27	88·74	46·09	177·48	92·19	266·22	138·29	354·96	184·39	443·70	230·49	33
30	88·70	46·17	177·40	92·35	266·10	138·52	354·80	184·70	443·50	230·87	30
33	88·66	46·25	177·32	92·50	265·98	138·76	354·64	185·01	443·30	231·26	27
36	88·62	46·32	177·24	92·65	265·86	138·99	354·48	185·31	443·10	231·64	24
39	88·58	46·40	177·16	92·81	265·74	139·22	354·32	185·62	442·90	232·03	21
42	88·53	46·48	177·07	92·96	265·61	139·45	354·15	185·93	442·69	232·42	18
45	88·49	46·56	176·99	93·11	265·49	139·68	353·99	186·24	442·49	232·81	15
48	88·45	46·63	176·91	93·27	265·37	139·91	353·83	186·55	442·29	233·19	12
51	88·41	46·71	176·83	93·42	265·25	140·14	353·67	186·86	442·09	233·58	9
54	88·37	46·79	176·75	93·58	265·12	140·37	353·50	187·17	441·88	233·96	6
57	88·33	46·86	176·67	93·73	265·00	140·60	353·34	187·48	441·68	234·35	3
60	88·29	46·94	176·59	93·89	264·88	140·84	353·18	187·78	441·47	234·73	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	534·60	272·39	623·70	317·79	712·80	363·19	801·90	408·59	891·00	453·99	60
3	534·36	272·86	623·42	318·34	712·48	363·81	801·55	409·29	890·60	454·77	57
6	534·12	273·32	623·14	318·88	712·16	364·43	801·19	409·99	890·20	455·54	54
9	533·88	273·79	622·87	319·42	711·85	365·05	800·83	410·69	889·80	456·32	51
12	533·64	274·25	622·59	319·96	711·53	365·67	800·47	411·38	889·40	457·09	48
15	533·40	274·72	622·31	320·51	711·21	366·29	800·11	412·08	889·01	457·87	45
18	533·16	275·18	622·03	321·05	710·89	366·91	799·75	412·78	888·61	458·64	42
21	532·92	275·65	621·75	321·59	710·57	367·53	799·39	413·48	888·21	459·42	39
24	532·68	276·11	621·47	322·13	710·25	368·15	799·03	414·18	887·81	460·19	36
27	532·44	276·58	621·19	322·67	709·93	368·77	798·67	414·88	887·41	460·97	33
30	532·20	277·04	620·90	323·22	709·60	369·39	798·31	415·57	887·00	461·74	30
33	531·96	277·51	620·62	323·76	709·28	370·01	797·95	416·27	886·60	462·51	27
36	531·72	277·97	620·34	324·30	708·96	370·63	797·58	416·96	886·20	463·29	24
39	531·48	278·44	620·06	324·84	708·64	371·25	797·22	417·66	885·80	464·07	21
42	531·23	278·90	619·77	325·38	708·31	371·87	796·85	418·35	885·39	464·84	18
45	530·99	279·37	619·49	325·92	707·99	372·49	796·49	419·05	884·98	465·61	15
48	530·74	279·83	619·20	326·47	707·66	373·10	796·12	419·74	884·57	466·38	12
51	530·50	280·29	618·92	327·01	707·34	373·72	795·76	420·44	884·17	467·15	9
54	530·25	280·75	618·63	327·55	707·01	374·34	795·39	421·13	883·76	467·92	6
57	530·01	281·22	618·35	328·09	706·69	374·96	795·02	421·83	883·36	468·69	3
60	529·77	281·68	618·06	328·63	706·36	375·57	794·65	422·52	882·95	469·47	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	88 29	46·94	176·59	93·89	264·88	140·84	353·18	187·78	441·47	234·73	60
3	88·25	47·02	176·51	94·04	264·76	141·07	353·02	188·09	441·27	235·12	57
6	88·21	47·10	176·42	94·20	264·63	141·30	352·85	188·40	441·06	235·50	54
9	88·17	47·17	176·34	94·35	264·51	141·53	352·69	188·71	440·86	235·89	51
12	88·13	47·25	176·26	94·51	264·39	141·76	352·52	189·02	440·65	236·27	48
15	88·08	47·33	176·18	94·66	264·27	141·99	352·35	189·33	440·44	236·66	45
18	88·04	47·40	176·09	94·81	264·14	142·22	352·18	189·63	440·23	237·04	42
21	88·00	47·48	176·01	94·96	264·02	142·45	352·02	189·94	440·03	237·43	39
24	87·96	47·56	175·92	95·12	263·89	142·68	351·85	190·24	439·82	237·81	36
27	87·92	47·63	175·84	95·27	263·77	142·91	351·69	190·55	439·61	238·19	33
30	87·88	47·71	175·76	95·43	263·64	143·13	351·52	190·86	439·40	238·57	30
33	87·84	47·79	175·68	95·58	263·52	143·36	351·35	191·17	439·20	238·95	27
36	87·79	47·86	175·59	95·73	263·39	143·60	351·18	191·47	438·99	239·34	24
39	87·75	47·94	175·51	95·88	263·27	143·83	351·02	191·78	438·78	239·72	21
42	87·71	48·02	175·42	96·04	263·14	144·06	350·85	192·08	438·57	240·11	18
45	87·67	48·09	175·34	96·19	263·02	144·29	350·69	192·39	438·36	240·49	15
48	87·63	48·17	175·26	96·35	262·89	144·52	350·52	192·70	438·15	240·87	12
51	87·58	48·25	175·18	96·50	262·76	144·75	350·35	193·01	437·94	241·25	9
54	87·54	48·32	175·09	96·65	262·63	144·98	350·18	193·31	437·73	241·64	6
57	87·50	48·40	175·01	96·80	262·51	145·21	350·01	193·62	437·52	242·02	3
60	87·46	48·48	174·92	96·96	262·38	145·44	349·84	193·92	437·31	242·40	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	529·77	281·68	618·06	328·63	706·36	375·57	794·65	422·52	882·95	469·47	60
3	529·52	282·14	617·77	329·17	706·03	376·19	794·28	423·22	882·54	470·24	57
6	529·27	282·60	617·48	329·70	705·70	376·80	793·91	423·91	882·12	471·01	54
9	529·03	283·06	617·20	330·24	705·37	377·42	793·54	424·60	881·71	471·78	51
12	528·78	283·53	616·91	330·78	705·04	378·04	793·17	425·29	881·30	472·55	48
15	528·53	283·99	616·62	331·32	704·71	378·66	792·80	425·98	880·89	473·32	45
18	528·28	284·45	616·33	331·86	704·38	379·27	792·43	426·67	880·47	474·08	42
21	528·03	284·91	616·04	332·40	704·05	379·89	792·06	427·36	880·06	474·85	39
24	527·78	285·37	615·75	332·93	703·71	380·50	791·68	428·06	879·64	475·62	36
27	527·54	285·83	615·46	333·47	703·38	381·11	791·31	428·75	879·23	476·39	33
30	527·29	286·29	615·16	334·01	703·05	381·72	790·93	429·44	878·81	477·15	30
33	527·04	286·75	614·87	334·55	702·71	382·33	790·56	430·13	878·40	477·92	27
36	526·79	287·21	614·58	335·08	702·38	382·95	790·18	430·82	877·98	478·69	24
39	526·54	287·67	614·29	335·62	702·05	383·56	789·81	431·51	877·56	479·46	21
42	526·28	288·13	614·00	336·15	701·71	384·17	789·43	432·20	877·14	480·22	18
45	526·03	288·59	613·71	336·69	701·38	384·78	789·05	432·89	876·72	480·99	15
48	525·78	289·05	613·41	337·22	701·04	385·40	788·67	433·57	876·30	481·76	12
51	525·53	289·51	613·12	337·76	700·70	386·01	788·29	434·26	875·88	482·52	9
54	525·27	289·96	612·82	338·29	700·37	386·62	787·91	434·95	875·46	483·28	6
57	525·02	290·42	612·53	338·83	700·03	387·23	787·53	435·04	875·04	484·04	3
60	524·77	290·88	612·23	339·36	699·69	387·84	787·15	436·33	874·62	484·80	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	87·46	48·48	174·92	96·96	262·38	145·44	349·84	193·92	437·31	242·40	60
3	87·42	48·55	174·84	97·11	262·26	145·67	349·67	194·22	437·10	242·78	57
6	87·37	48·63	174·75	97·26	262·13	145·90	349·50	194·53	436·88	243·16	54
9	87·33	48·70	174·67	97·41	262·00	146·13	349·33	194·83	436·67	243·54	51
12	87·29	48·78	174·58	97·57	261·87	146·35	349·16	195·14	436·46	243·92	48
15	87·25	48·86	174·50	97·72	261·75	146·58	348·99	195·44	436·25	244·30	45
18	87·20	48·93	174·41	97·87	261·62	146·81	348·82	195·75	436·03	244·69	42
21	87·16	49·01	174·33	98·02	261·49	147·04	348·65	196·05	435·82	245·07	39
24	87·12	49·09	174·24	98·18	261·36	147·27	348·48	196·36	435·60	245·45	36
27	87·07	49·16	174·16	98·33	261·23	147·50	348·31	196·66	435·39	245·83	33
30	87·03	49·24	174·07	98·48	261·10	147·72	348·14	196·96	435·17	246·21	30
33	86·99	49·31	173·98	98·63	260·97	147·95	347·97	197·26	434·96	246·59	27
36	86·94	49·39	173·89	98·78	260·84	148·18	347·79	197·57	434·74	246·97	24
39	86·90	49·47	173·81	98·93	260·71	148·41	347·62	197·87	434·53	247·35	21
42	86·86	49·54	173·72	99·09	260·58	148·63	347·45	198·18	434·31	247·72	18
45	86·82	49·62	173·64	99·24	260·45	148·86	347·28	198·48	434·10	248·10	15
48	86·77	49·69	173·55	99·39	260·32	149·09	347·10	198·78	433·88	248·48	12
51	86·73	49·77	173·46	99·54	260·19	149·32	346·93	199·08	433·66	248·86	9
54	86·68	49·84	173·37	99·69	260·06	149·54	346·75	199·39	433·44	249·24	6
57	86·64	49·92	173·29	99·84	259·93	149·77	346·58	199·69	433·23	249·62	3
60	86·60	50·00	173·20	100·00	259·80	150·00	346·40	200·00	433·01	250·00	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	524·77	290·88	612·23	339·36	699·69	387·84	787·15	436·33	874·62	484·80	60
3	524·52	291·34	611·94	339·89	699·35	388·45	786·77	437·02	874·20	485·56	57
6	524·26	291·80	611·64	340·43	699·01	389·06	786·39	437·70	873·77	486·33	54
9	524·01	292·26	611·34	340·96	698·67	389·67	786·01	438·39	873·35	487·09	51
12	523·75	292·71	611·04	341·50	698·33	390·28	785·63	439·07	872·92	487·85	48
15	523·50	293·17	610·74	342·03	697·99	390·89	785·25	439·76	872·50	488·61	45
18	523·24	293·62	610·44	342·56	697·65	391·50	784·86	440·44	872·07	489·38	42
21	522·98	294·08	610·14	343·09	697·31	392·11	784·48	441·13	871·64	490·14	39
24	522·72	294·54	609·84	343·63	696·97	392·72	784·09	441·81	871·21	490·90	36
27	522·47	295·00	609·54	344·16	696·63	393·33	783·71	442·50	870·78	491·66	33
30	522·21	295·45	609·24	344·69	696·28	393·93	783·32	443·18	870·35	492·42	30
33	521·95	295·91	608·94	345·22	695·94	394·54	782·93	443·87	869·92	493·18	27
36	521·69	296·36	608·64	345·75	695·59	395·15	782·54	444·55	869·49	493·94	24
39	521·43	296·82	608·34	346·28	695·25	395·76	782·15	445·23	869·06	494·70	21
42	521·17	297·27	608·04	346·82	694·90	396·36	781·76	445·91	868·63	495·45	18
45	520·91	297·73	607·74	347·35	694·56	396·96	781·37	446·59	868·20	496·21	15
48	520·65	298·18	607·43	347·88	694·21	397·57	780·98	447·27	867·76	496·97	12
51	520·39	298·64	607·13	348·41	693·86	398·18	780·59	447·95	867·33	497·73	9
54	520·13	299·09	606·82	348·94	693·51	398·78	780·20	448·63	866·89	498·48	6
57	519·87	299·55	606·52	349·47	693·16	399·39	779·81	449·31	866·46	499·24	3
60	519·61	300·00	606·21	350·00	692·81	400·00	779·42	450·00	866·02	500·00	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	86·60	50·00	173·20	100·00	259·80	150·00	346·40	200·00	433·01	250·00	60
3	86·55	50·07	173·12	100·15	259·67	150·23	346·23	200·30	432·79	250·38	57
6	86·51	50·15	173·03	100·30	259·54	150·45	346·05	200·60	432·57	250·75	54
9	86·47	50·22	172·94	100·45	259·41	150·68	345·88	200·90	432·35	251·13	51
12	86·42	50·30	172·85	100·60	259·28	150·90	345·70	201·20	432·13	251·50	48
15	86·38	50·37	172·76	100·75	259·15	151·13	345·53	201·50	431·91	251·88	45
18	86·33	50·45	172·67	100·90	259·01	151·35	345·35	201·81	431·69	252·26	42
21	86·29	50·52	172·59	101·05	258·88	151·58	345·18	202·11	431·47	252·64	39
24	86·25	50·60	172·50	101·20	258·75	151·80	345·00	202·41	431·25	253·01	36
27	86·20	50·67	172·41	101·35	258·62	152·03	344·83	202·71	431·03	253·39	33
30	86·16	50·75	172·32	101·50	258·48	152·26	344·65	203·01	430·81	253·76	30
33	86·11	50·82	172·23	101·65	258·35	152·49	344·47	203·31	430·59	254·14	27
36	86·07	50·90	172·14	101·80	258·22	152·71	344·29	203·61	430·37	254·52	24
39	86·03	50·97	172·06	101·95	258·09	152·94	344·12	203·91	430·15	254·90	21
42	85·98	51·05	171·97	102·10	257·95	153·16	343·94	204·21	429·92	255·27	18
45	85·94	51·12	171·88	102·25	257·82	153·39	343·76	204·51	429·70	255·65	15
48	85·89	51·20	171·79	102·40	257·68	153·61	343·58	204·81	429·48	256·02	12
51	85·85	51·27	171·70	102·55	257·55	153·84	343·40	205·11	429·26	256·40	9
54	85·80	51·35	171·61	102·70	257·41	154·06	343·22	205·41	429·03	256·77	6
57	85·76	51·42	171·52	102·85	257·28	154·29	343·04	205·71	428·81	257·14	3
60	85·71	51·50	171·43	103·00	257·15	154·51	342·86	206·01	428·58	257·51	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	519·61	300·00	606·21	350·00	692·81	400·00	779·42	450·00	866·02	500·00	60
3	519·35	300·45	605·91	350·53	692·47	400·60	779·03	450·68	865·59	500·76	57
6	519·09	300·90	605·60	351·05	692·12	401·20	778·63	451·36	865·15	501·51	54
9	518·83	301·35	605·30	351·58	691·77	401·80	778·24	452·04	864·71	502·26	51
12	518·56	301·81	604·99	352·11	691·41	402·41	777·84	452·71	864·27	503·01	48
15	518·30	302·26	604·68	352·64	691·06	403·01	777·45	453·39	863·83	503·76	45
18	518·03	302·71	604·37	353·16	690·71	403·62	777·05	454·07	863·39	504·52	42
21	517·77	303·16	604·06	353·69	690·36	404·22	776·66	454·75	862·95	505·27	39
24	517·50	303·61	603·75	354·22	690·01	404·82	776·26	455·43	862·51	506·03	36
27	517·24	304·06	603·45	354·75	689·66	405·42	775·86	456·11	862·07	506·78	33
30	516·97	304·52	603·14	355·27	689·30	406·03	775·46	456·78	861·62	507·53	30
33	516·71	304·97	602·83	355·80	688·95	406·63	775·06	457·46	861·18	508·28	27
36	516·44	305·42	602·52	356·32	688·59	407·23	774·66	458·13	860·74	509·04	24
39	516·17	305·87	602·21	356·85	688·24	407·83	774·26	458·81	860·30	509·79	21
42	515·90	306·33	601·89	357·38	687·88	408·43	773·86	459·48	859·85	510·54	18
45	515·64	306·78	601·58	357·91	687·52	409·03	773·46	460·16	859·40	511·29	15
48	515·37	307·23	601·27	358·43	687·16	409·63	773·06	460·83	858·95	512·04	12
51	515·10	307·68	600·96	358·95	686·81	410·23	772·66	461·51	858·51	512·79	9
54	514·83	308·13	600·64	359·47	686·45	410·83	772·25	462·18	858·06	513·54	6
57	514·57	308·58	600·33	359·99	686·09	411·43	771·85	462·86	857·61	514·29	3
60	514·30	309·02	600·01	360·52	685·73	412·03	771·45	463·53	857·16	515·04	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	85·71	51·50	171·43	103·00	257·15	154·51	342·86	206·01	428·58	257·51	60
3	85·67	51·57	171·34	103·15	257·02	154·73	342·68	206·31	428·36	257·88	57
6	85·62	51·65	171·25	103·30	256·88	154·95	342·50	206·61	428·13	258·26	54
9	85·58	51·72	171·16	103·45	236·74	155·17	342·32	206·91	427·91	258·63	51
12	85·53	51·80	171·07	103·60	256·60	155·40	342·14	207·21	427·68	259·01	48
15	85·49	51·87	170·98	103·75	256·47	155·62	341·96	207·51	427·46	259·38	45
18	85·44	51·95	170·89	103·90	256·33	155·85	341·78	207·80	427·23	259·75	42
21	85·40	52·02	170·80	104·05	256·20	156·07	341·60	208·10	427·00	260·12	39
24	85·35	52·10	170·70	104·20	256·06	156·30	341·41	208·40	426·77	260·50	36
27	85·31	52·17	170·61	104·35	255·93	156·52	341·23	208·70	426·55	260·87	33
30	85·26	52·24	170·52	104·50	255·79	156·74	341·05	209·00	426·32	261·24	30
33	85·21	52·32	170·43	104·65	255·65	156·96	340·87	209·30	426·09	261·62	27
36	85·17	52·39	170·34	104·79	255·51	157·19	340·69	209·59	425·86	261·99	24
39	85·12	52·47	170·25	104·94	255·38	157·41	340·51	209·89	425·63	262·36	21
42	85·08	52·54	170·16	105·09	255·24	157·64	340·32	210·19	425·40	262·73	18
45	85·03	52·62	170·07	105·24	255·10	157·86	340·14	210·49	425·17	263·10	15
48	84·98	52·69	169·97	105·39	254·96	158·08	339·95	210·79	424·94	263·47	12
51	84·94	52·76	169·88	105·54	254·83	158·30	339·77	211·08	424·71	263·84	9
54	84·89	52·84	169·79	105·68	254·69	158·53	339·58	211·37	424·48	264·21	6
57	84·85	52·91	169·70	105·83	254·55	158·75	339·40	211·67	424·28	264·58	3
60	84·80	52·99	169·60	105·98	254·41	158·97	339·21	211·96	424·02	264·95	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	514·30	309·02	600·01	360·52	685·73	412·03	771·45	463·53	857·16	515·04	60
3	514·03	309·47	599·70	361·04	685·37	412·63	771·05	464·20	856·71	515·79	57
6	513·76	309·91	599·38	361·57	685·01	413·22	770·64	464·88	856·26	516·53	54
9	513·49	310·36	599·07	362·09	684·65	413·82	770·23	465·55	855·81	517·28	51
12	513·21	310·81	598·75	362·61	684·29	414·42	769·83	466·22	855·36	518·02	48
15	512·94	311·26	598·44	363·13	683·93	415·02	769·42	466·89	854·91	518·77	45
18	512·67	311·71	598·12	363·66	683·56	415·61	769·01	467·56	854·45	519·51	42
21	512·40	312·15	597·80	364·18	683·20	416·21	768·60	468·23	854·00	520·26	39
24	512·13	312·60	597·48	364·70	682·83	416·80	768·19	468·90	853·55	521·00	36
27	511·86	313·05	597·16	365·22	682·47	417·40	767·78	469·57	853·10	521·75	33
30	511·58	313·49	596·84	365·74	682·11	418·00	767·37	470·24	852·64	522·49	30
33	511·31	313·94	596·52	366·27	681·75	418·59	766·94	470·91	852·18	523·24	27
36	511·03	314·39	596·20	366·79	681·38	419·18	766·55	471·58	851·72	523·98	24
39	510·76	314·84	595·88	367·31	681·01	419·78	766·14	472·25	851·27	524·73	21
42	510·48	315·28	595·56	367·83	680·64	420·37	765·73	472·92	850·81	525·47	18
45	510·21	315·73	595·24	368·35	680·28	420·97	765·32	473·59	850·35	526·21	15
48	509·93	316·17	594·92	368·87	679·91	421·56	764·90	474·26	849·89	526·95	12
51	509·66	316·62	594·60	369·39	679·54	422·16	764·49	474·93	849·43	527·69	9
54	509·38	317·06	594·28	369·90	679·17	422·75	764·07	475·59	848·97	528·43	6
57	509·10	317·51	593·96	370·42	678·80	423·34	763·66	476·26	848·51	529·17	3
60	508·82	317·95	593·63	370·94	678·43	423·93	763·24	476·92	848·04	529·91	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	84·80	52·99	169·60	105·98	254·41	158·97	339·21	211·96	424·02	264·95	60
3	84·75	53·06	169·51	106·13	254·27	159·19	339·03	212·25	423·79	265·32	57
6	84·71	53·13	169·42	106·27	254·13	159·41	338·84	212·55	423·56	265·69	54
9	84·66	53·21	169·33	106·42	253·99	159·63	338·66	212·85	423·33	266·06	51
12	84·61	53·28	169·23	106·57	253·85	159·86	338·47	213·15	423·09	266·43	48
15	84·57	53·36	169·14	106·72	253·71	160·08	338·29	213·45	422·86	266·80	45
18	84·52	53·43	169·05	106·87	253·57	160·30	338·10	213·74	422·63	267·17	42
21	84·47	53·50	168·96	107·02	253·43	160·52	337·92	214·04	422·40	267·54	39
24	84·43	53·58	168·86	107·16	253·29	160·74	337·73	214·33	422·16	267·91	36
27	84·38	53·65	168·77	107·31	253·15	160·96	337·54	214·63	421·93	268·28	33
30	84·33	53·73	168·67	107·46	253·01	161·18	337·35	214·92	421·69	268·65	30
33	84·29	53·80	168·58	107·61	252·87	161·40	337·17	215·21	421·46	269·02	27
36	84·24	53·87	168·49	107·75	252·73	161·62	336·98	215·50	421·22	269·38	24
39	84·19	53·95	168·40	107·90	252·59	161·85	336·79	215·80	420·99	269·75	21
42	84·15	54·02	168·30	108·04	252·45	162·07	336·60	216·09	420·75	270·12	18
45	84·10	54·09	168·21	108·19	252·31	162·29	336·41	216·39	420·52	270·49	15
48	84·05	54·17	168·11	108·34	252·17	162·51	336·22	216·68	420·28	270·85	12
51	84·01	54·24	168·02	108·49	252·03	162·73	336·03	216·97	420·05	271·22	9
54	83·96	54·31	167·92	108·63	251·88	162·95	335·84	217·26	419·81	271·58	6
57	83·91	54·39	167·83	108·78	251·74	163·17	335·65	217·56	419·57	271·95	3
60	83·86	54·46	167·73	108·92	251·60	163·38	335·46	217·85	419·33	272·31	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	508·82	317·95	593·63	370·94	678·43	423·93	763·24	476·92	848·04	529·91	60
3	508·55	318·39	593·31	371·46	678·06	424·52	762·82	477·58	847·58	530·65	57
6	508·27	318·83	592·98	371·97	677·69	425·11	762·40	478·25	847·11	531·39	54
9	507·99	319·27	592·66	372·49	677·32	425·70	761·99	478·92	846·65	532·13	51
12	507·71	319·72	592·33	373·01	676·95	426·30	761·57	479·59	846·19	532·87	48
15	507·43	320·16	592·01	373·53	676·58	426·89	761·15	480·25	845·73	533·61	45
18	507·15	320·61	591·68	374·04	676·20	427·48	760·73	480·91	845·26	534·35	42
21	506·87	321·05	591·36	374·56	675·83	428·07	760·31	481·57	844·79	535·09	39
24	506·59	321·49	591·03	375·07	675·46	428·66	759·89	482·24	844·32	535·82	36
27	506·31	321·93	590·70	375·59	675·09	429·25	759·47	482·90	843·86	536·56	33
30	506·03	322·37	590·37	376·10	674·71	429·84	759·05	483·56	843·39	537·30	30
33	505·75	322·81	590·04	376·62	674·34	430·43	758·63	484·23	842·92	538·04	27
36	505·47	323·26	589·71	377·13	673·96	431·01	758·20	484·89	842·45	538·77	24
39	505·19	323·70	589·38	377·65	673·58	431·60	757·78	485·55	841·98	539·51	21
42	504·90	324·14	589·05	378·16	673·20	432·19	757·36	486·21	841·51	540·24	18
45	504·62	324·58	588·72	378·68	672·83	432·78	756·94	486·89	841·04	540·97	15
48	504·33	325·02	588·39	379·19	672·45	433·36	756·51	487·53	840·56	541·70	12
51	504·05	325·46	588·06	379·71	672·07	433·95	756·08	488·19	840·09	542·44	9
54	503·77	325·90	587·73	380·22	671·69	434·53	755·65	488·85	839·61	543·17	6
57	503·49	326·34	587·40	380·73	671·31	435·12	755·23	489·51	839·14	543·90	3
60	503·20	326·78	587·07	381·24	670·93	435·71	754·80	490·17	838·67	544·63	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	83·86	54·46	167·73	108·92	251·60	163·38	335·46	217·85	419·33	272·31	60
3	83·81	54·53	167·64	109·07	251·46	163·60	335·27	218·14	419·09	272·68	57
6	83·77	54·61	167·54	109·22	251·31	163·82	335·08	218·44	418·85	273·05	54
9	83·72	54·68	167·45	109·37	251·17	164·04	334·89	218·73	418·62	273·42	51
12	83·67	54·75	167·35	109·51	251·02	164·26	334·70	219·02	418·38	273·78	48
15	83·62	54·82	167·26	109·66	250·88	164·48	334·51	219·31	418·14	274·15	45
18	83·58	54·90	167·16	109·80	250·74	164·70	334·32	219·60	417·90	274·51	42
21	83·53	54·97	167·06	109·95	250·60	164·92	334·13	219·89	417·66	274·88	39
24	83·48	55·04	166·96	110·09	250·45	165·14	333·93	220·19	417·42	275·24	36
27	83·43	55·12	166·87	110·24	250·31	165·36	333·74	220·48	417·18	275·60	33
30	83·38	55·19	166·77	110·38	250·16	165·58	333·55	220·77	416·94	275·96	30
33	83·34	55·26	166·68	110·53	250·02	165·80	333·36	221·06	416·70	276·33	27
36	83·29	55·33	166·58	110·67	249·87	166·01	333·16	221·35	416·46	276·69	24
39	83·24	55·41	166·49	110·82	249·73	166·23	332·97	221·64	416·22	277·06	21
42	83·19	55·48	166·39	110·96	249·58	166·45	332·78	221·93	415·97	277·42	18
45	83·14	55·55	166·29	111·11	249·44	166·67	332·59	222·22	415·73	277·78	15
48	83·09	55·62	166·19	111·25	249·29	166·88	332·39	222·51	415·49	278·14	12
51	83·05	55·70	166·10	111·40	249·15	167·10	332·20	222·80	415·25	278·50	9
54	83·00	55·77	166·00	111·54	249·00	167·32	332·00	223·09	415·00	278·87	6
57	82·95	55·84	165·90	111·69	248·86	167·54	331·81	223·38	414·76	279·23	3
60	82·90	55·91	165·80	111·83	248·71	167·75	331·61	223·67	414·51	279·59	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	503·20	326·78	587·07	381·24	670·93	435·71	754·80	490·17	838·67	544·63	60
3	502·92	327·22	586·74	381·76	670·55	436·29	754·37	490·83	838·19	545·36	57
6	502·63	327·66	586·40	382·27	670·17	436·88	753·94	491·49	837·71	546·10	54
9	502·34	328·10	586·07	382·79	669·79	437·46	753·51	492·15	837·24	546·83	51
12	502·05	328·53	585·73	383·30	669·41	438·05	753·08	492·80	836·76	547·56	48
15	501·77	328·97	585·40	383·81	669·03	438·63	752·65	493·46	836·28	548·29	45
18	501·48	329·41	585·06	384·32	668·64	439·21	752·22	494·12	835·80	549·02	42
21	501·19	329·85	584·72	384·83	668·26	439·79	751·79	494·78	835·32	549·75	39
24	500·90	330·28	584·39	385·34	667·87	440·38	751·36	495·43	834·84	550·48	36
27	500·62	330·72	584·05	385·85	667·49	440·96	750·93	496·09	834·36	551·21	33
30	500·33	331·16	583·71	386·36	667·10	441·54	750·49	496·74	833·88	551·93	30
33	500·04	331·60	583·38	386·87	666·72	442·12	750·06	497·40	833·40	552·66	27
36	499·75	332·03	583·04	387·38	666·33	442·70	749·62	498·05	832·91	553·39	24
39	499·46	332·47	582·70	387·89	665·95	443·29	749·19	498·71	832·43	554·12	21
42	499·17	332·90	582·36	388·39	665·56	443·87	748·75	499·36	831·95	554·84	18
45	498·88	333·34	582·02	388·90	665·17	444·45	748·32	500·01	831·47	555·57	15
48	498·58	333·77	581·68	389·40	664·78	445·03	747·88	500·66	830·98	556·29	12
51	498·29	334·21	581·34	389·91	664·39	445·61	747·45	501·32	830·50	557·02	9
54	498·00	334·64	581·00	390·42	664·00	446·19	747·01	501·97	830·01	557·74	6
57	497·71	335·08	580·66	390·92	663·61	446·77	746·57	502·62	829·52	558·47	3
60	497·42	335·51	580·32	391·43	663·22	447·35	746·13	503·27	829·03	559·19	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	82 90	55·91	165·80	111·83	248·71	167·75	331·61	223·67	414·51	279·59	60
3	82·85	55·99	165·71	111·97	248·56	167·97	331·42	223·96	414·27	279·95	57
6	82·80	56·06	165·61	112·12	248·41	168·19	331·22	224·25	414·03	280·31	54
9	82·75	56·13	165·51	112·26	248·27	168·41	331·03	224·54	413·78	280·67	51
12	82·70	56·20	165·41	112·41	248·12	168·62	330·83	224·83	413·53	281·04	48
15	82·65	56·28	165·31	112·55	247·97	168·84	330·63	225·12	413·29	281·40	45
18	82·60	56·35	165·21	112·70	247·82	169·05	330·43	225·41	413·04	281·76	42
21	82·56	56·42	165·12	112·84	247·68	169·27	330·24	225·70	412·80	282·12	39
24	82·51	56·49	165·02	112·99	247·53	169·48	330·04	225·98	412·55	282·48	36
27	82·46	56·56	164·92	113·13	247·38	169·70	329·85	226·27	412·31	282·84	33
30	82·41	56·64	164·82	113·28	247·23	169·92	329·65	226·56	412·06	283·20	30
33	82·36	56·71	164·72	113·42	247·09	170·14	329·45	226·85	411·81	283·56	27
36	82·31	56·78	164·62	113·56	246·94	170·35	329·25	227·13	411·56	283·92	24
39	82·26	56·85	164·52	113·70	246·79	170·57	329·05	227·42	411·32	284·28	21
42	82·21	56·92	164·42	113·85	246·64	170·78	328·85	227·71	411·07	284·63	18
45	82·16	56·99	164·33	113·99	246·49	170·99	328·65	227·99	410·82	284·99	15
48	82·11	57·07	164·23	114·14	246·34	171·21	328·45	228·28	410·57	285·35	12
51	82·06	57·14	164·13	114·28	246·19	171·43	328·26	228·57	410·32	285·71	9
54	82·01	57·21	164·03	114·42	246·04	171·64	328·06	228·85	410·07	286·07	6
57	81·96	57·28	163·93	114·56	245·89	171·86	327·86	229·14	409·82	286·43	3
60	81·91	57·35	163·83	114·71	245·74	172·07	327·66	229·43	409·57	286·78	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	497·42	335·51	580·32	391·43	663·22	447·35	746·13	503·27	829·03	559·19	60
3	497·13	335·94	579·98	391·93	662·83	447·93	745·69	503·92	828·54	559·91	57
6	496·83	336·38	579·64	392·44	662·44	448·51	745·25	504·57	828·05	560·63	54
9	496·54	336·81	579·30	392·94	662·05	449·09	744·81	505·22	827·56	561·35	51
12	496·24	337·24	578·95	393·45	661·66	449·66	744·37	505·87	827·07	562·08	48
15	495·95	337·67	578·61	393·95	661·27	450·24	743·93	506·52	826·58	562·80	45
18	495·65	338·11	578·26	394·46	660·87	450·82	743·48	507·17	826·09	563·52	42
21	495·36	338·54	577·92	394·96	660·48	451·40	743·04	507·82	825·60	564·24	39
24	495·06	338·97	577·57	395·47	660·09	451·97	742·60	508·47	825·11	564·96	36
27	494·77	339·40	577·23	395·97	659·70	452·55	742·16	509·12	824·62	565·68	33
30	494·47	339·84	576·88	396·48	659·30	453·12	741·71	509·76	824·12	566·40	30
33	494·18	340·27	576·54	396·98	658·90	453·70	741·27	510·41	823·63	567·12	27
36	493·88	340·70	576·19	397·49	658·50	454·27	740·82	511·05	823·13	567·84	24
39	493·58	341·13	575·85	397·99	658·11	454·85	740·37	511·70	822·64	568·56	21
42	493·28	341·56	575·50	398·49	657·71	455·42	739·92	512·35	822·14	569·27	18
45	492·99	341·99	575·15	398·99	657·32	455·99	739·48	512·99	821·64	569·99	15
48	492·69	342·42	574·80	399·49	656·92	456·57	739·03	513·64	821·14	570·71	12
51	492·39	342·85	574·45	399·99	656·52	457·14	738·58	514·29	820·65	571·43	9
54	492·09	343·28	574·10	400·50	656·12	457·71	738·13	514·93	820·15	572·14	6
57	491·79	343·71	573·75	401·00	655·72	458·28	737·68	515·57	819·65	572·86	3
60	491·49	344·14	573·40	401·50	655·32	458·86	737·23	516·21	819·15	573·57	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	81·91	57·35	163·83	114·71	245·74	172·07	327·66	229·43	409·57	286·78	60
3	81·86	57·42	163·72	114·85	245·59	172·28	327·46	229·72	409·32	287·14	57
6	81·81	57·50	163·62	115·00	245·44	172·50	327·26	230·00	409·07	287·50	54
9	81·76	57·57	163·52	115·14	245·29	172·71	327·06	230·29	408·82	287·86	51
12	81·71	57·64	163·42	115·28	245·14	172·92	326·85	230·57	408·57	288·21	48
15	81·66	57·71	163·32	115·42	244·99	173·13	326·65	230·86	408·32	288·57	45
18	81·61	57·78	163·22	115·57	244·84	173·35	326·45	231·14	408·07	288·92	42
21	81·56	57·86	163·12	115·71	244·69	173·56	326·25	231·43	407·82	289·28	39
24	81·51	57·93	163·02	115·85	244·53	173·78	326·05	231·71	407·56	289·64	36
27	81·46	58·00	162·92	115·99	244·38	173·99	325·85	232·00	407·31	290·00	33
30	81·41	58·07	162·82	116·14	244·23	174·21	325·64	232·28	407·05	290·35	30
33	81·36	58·14	162·72	116·28	244·08	174·42	325·44	232·57	406·80	290·71	27
36	81·31	58·21	162·62	116·42	243·93	174·63	325·24	232·85	406·55	291·06	24
39	81·26	58·28	162·52	116·56	243·78	174·84	325·04	233·13	406·30	291·42	21
42	81·21	58·35	162·41	116·70	243·62	175·06	324·83	233·41	406·04	291·77	18
45	81·16	58·42	162·31	116·84	243·47	175·27	324·63	233·70	405·79	292·12	15
48	81·10	58·49	162·21	116·99	243·31	175·48	324·42	233·98	405·53	292·47	12
51	81·05	58·57	162·11	117·13	243·16	175·69	324·22	234·27	405·28	292·83	9
54	81·00	58·64	162·00	117·27	243·01	175·91	324·01	234·55	405·02	293·18	6
57	80·95	58·71	161·90	117·41	242·86	176·12	323·81	234·83	404·76	293·54	3
60	80·90	58·78	161·80	117·55	242·70	176·33	323·60	234·11	404·50	293·89	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	491·49	344·14	573·40	401·50	655·32	458·86	737·23	516·21	819·15	573·57	60
3	491·19	344·57	573·05	402·00	654·92	459·43	736·78	516·85	818·65	574·28	57
6	490·88	345·00	572·70	402·50	654·51	460·00	736·33	517·50	818·14	575·00	54
9	490·58	345·43	572·35	403·00	654·11	460·57	735·88	518·14	817·64	575·71	51
12	490·28	345·85	572·00	403·50	653·71	461·14	735·42	518·78	817·14	576·43	48
15	489·98	346·28	571·65	404·00	653·31	461·71	734·97	519·42	816·64	577·14	45
18	489·68	346·71	571·29	404·50	652·90	462·28	734·52	520·07	816·13	577·85	42
21	489·38	347·14	570·94	405·00	652·50	462·85	734·07	520·71	815·63	578·56	39
24	489·07	347·57	570·58	405·50	652·10	463·42	733·61	521·35	815·12	579·28	36
27	488·77	348·00	570·23	406·00	651·70	464·00	733·16	522·00	814·62	580·00	33
30	488·46	348·42	569·88	406·49	651·29	464·57	732·70	522·64	814·11	580·71	30
33	488·16	348·85	569·53	406·99	650·89	465·13	732·25	523·27	813·61	581·42	27
36	487·86	349·27	569·17	407·49	650·48	465·70	731·79	523·91	813·10	582·13	24
39	487·56	349·70	568·81	407·98	650·07	466·26	731·33	524·55	812·59	582·84	21
42	487·25	350·12	568·45	408·48	649·66	466·83	730·87	525·18	812·08	583·54	18
45	486·94	350·55	568·10	408·97	649·26	467·39	730·41	525·82	811·57	584·25	15
48	486·63	350·97	567·74	409·47	648·85	467·96	729·95	526·46	811·06	584·95	12
51	486·33	351·40	567·38	409·96	648·44	468·52	729·49	527·10	810·55	585·66	9
54	486·02	351·82	567·03	410·46	648·03	469·09	729·03	527·73	810·04	586·37	6
57	485·71	352·25	566·67	410·95	647·62	469·65	728·57	528·37	809·53	587·07	3
60	485·40	352·67	566·31	411·45	647·21	470·22	728·11	529·00	809·01	587·78	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	80·90	58·78	161·80	117·55	242·70	176·33	323·60	235·11	404·50	293·89	60
3	80·85	58·85	161·70	117·69	242·55	176·54	323·40	235·39	404·25	294·24	57
6	80·80	58·92	161·59	117·83	242·39	176·75	323·19	235·67	403·99	294·59	54
9	80·74	58·99	161·49	117·97	242·24	176·96	322·99	235·95	403·74	294·94	51
12	80·69	59·06	161·39	118·12	242·08	177·18	322·78	236·24	403·48	295·30	48
15	80·64	59·13	161·29	118·26	241·93	177·39	322·58	236·52	403·22	295·65	45
18	80·59	59·20	161·18	118·40	241·77	177·60	322·37	236·80	402·96	296·00	42
21	80·54	59·27	161·08	118·54	241·62	177·81	322·16	237·08	402·70	296·35	39
24	80·49	59·34	160·97	118·68	241·46	178·02	321·95	237·36	402·44	296·70	36
27	80·43	59·41	160·87	118·82	241·31	178·23	321·75	237·64	402·18	297·05	33
30	80·38	59·48	160·77	118·96	241·15	178·44	321·54	237·92	401·92	297·41	30
33	80·33	59·55	160·67	119·10	241·00	178·65	321·33	238·20	401·66	297·76	27
36	80·28	59·62	160·56	119·24	240·84	178·86	321·12	238·48	401·40	298·11	24
39	80·23	59·69	160·46	119·38	240·69	179·07	320·92	238·76	401·14	298·46	21
42	80·18	59·76	160·35	119·52	240·53	179·28	320·71	239·04	400·88	298·81	18
45	80·12	59·83	160·25	119·66	240·37	179·49	320·50	239·32	400·62	299·16	15
48	80·07	59·90	160·14	119·80	240·21	179·70	320·29	239·60	400·36	299·51	12
51	80·02	59·97	160·04	119·94	240·06	179·91	320·08	239·88	400·10	299·86	9
54	79·97	60·04	159·93	120·08	239·90	180·12	319·87	240·16	399·84	300·21	6
57	79·92	60·11	159·83	120·22	239·75	180·33	319·66	240·44	399·58	300·56	3
60	79·86	60·18	159·72	120·36	239·59	180·54	319·45	240·72	399·31	300·90	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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0	485·40	352·67	566·31	411·45	647·21	470·22	728·11	529·00	809·01	587·78	60
3	485·10	353·09	565·95	411·94	646·80	470·79	727·65	529·64	808·50	588·49	57
6	484·79	353·51	565·59	412·43	646·39	471·35	727·19	530·27	807·98	589·19	54
9	484·48	353·93	565·23	412·92	645·98	471·91	726·73	530·90	807·47	589·90	51
12	484·17	354·36	564·87	413·42	645·57	472·48	726·26	531·54	806·95	590·60	48
15	483·86	354·78	564·51	413·91	645·16	473·04	725·80	532·17	806·44	591·31	45
18	483·55	355·20	564·15	414·40	644·74	473·60	725·33	532·81	805·92	592·01	42
21	483·24	355·62	563·79	414·89	644·33	474·17	724·87	533·44	805·41	592·72	39
24	482·93	356·05	563·42	415·39	643·91	474·73	724·40	534·07	804·89	593·42	36
27	482·62	356·47	563·06	415·88	643·50	475·29	723·94	534·70	804·37	594·12	33
30	482·31	356·89	562·70	416·37	643·08	475·85	723·47	535·34	803·85	594·82	30
33	482·00	357·31	562·34	416·86	642·67	476·41	723·00	535·97	803·33	595·52	27
36	481·69	357·73	561·97	417·35	642·25	476·98	722·53	536·60	802·81	596·22	24
39	481·38	358·15	561·61	417·84	641·84	477·54	722·06	537·23	802·29	596·92	21
42	481·06	358·57	561·24	418·33	641·42	478·10	721·59	537·85	801·77	597·62	18
45	480·75	358·99	560·88	418·82	641·00	478·66	721·12	538·48	801·25	598·32	15
48	480·43	359·41	560·51	419·31	640·58	479·21	720·65	539·11	800·73	599·02	12
51	480·12	359·83	560·15	419·80	640·16	479·77	720·18	539·74	800·21	599·72	9
54	479·81	360·25	559·78	420·29	639·74	480·33	719·71	540·37	799·68	600·42	6
57	479·50	360·67	559·41	420·78	639·32	480·89	719·24	541·00	799·16	601·12	3
60	479·18	361·09	559·04	421·27	638·90	481·45	718·77	541·63	798·63	601·81	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	79·86	60·18	159·72	120·36	239·59	180·54	319·45	240·72	399·31	300·90	60
3	79·81	60·25	159·62	120·50	239·43	180·75	319·24	241·00	399·05	301·25	57
6	79·75	60·32	159·51	120·64	239·27	180·96	319·03	241·28	398·79	301·60	54
9	79·70	60·39	159·41	120·78	239·11	181·17	318·82	241·56	398·53	301·95	51
12	79·65	60·46	159·30	120·92	238·95	181·38	318·61	241·84	398·26	302·30	48
15	79·60	60·53	159·20	121·06	238·80	181·58	318·40	242·12	398·00	302·65	45
18	79·55	60·60	159·09	121·19	238·64	181·79	318·19	242·39	397·73	302·99	42
21	79·49	60·67	158·99	121·33	238·48	182·00	317·98	242·67	397·47	303·34	39
24	79·44	60·74	158·88	121·47	238·32	182·21	317·76	242·94	397·20	303·69	36
27	79·39	60·81	158·78	121·61	238·16	182·42	317·55	243·22	396·94	304·03	33
30	79·33	60·88	158·67	121·75	238·00	182·62	317·34	243·50	396·67	304·38	30
33	79·28	60·95	158·56	121·89	237·84	182·83	317·13	243·78	396·41	304·73	27
36	79·23	61·01	158·45	122·02	237·68	183·04	316·91	244·05	396·14	305·07	24
39	79·18	61·08	158·35	122·16	237·52	183·25	316·70	244·33	395·88	305·42	21
42	79·12	61·15	158·24	122·30	237·36	183·46	316·49	244·61	395·61	305·76	18
45	79·07	61·22	158·14	122·44	237·20	183·67	316·28	244·89	395·35	306·11	15
48	79·01	61·29	158·03	122·58	237·04	183·87	316·06	245·16	395·08	306·45	12
51	78·96	61·36	157·92	122·72	236·88	184·08	315·85	245·44	394·81	306·80	9
54	78·91	61·43	157·81	122·85	236·72	184·28	315·63	245·71	394·54	307·14	6
57	78·85	61·50	157·71	122·99	236·56	184·49	315·42	245·99	394·27	307·49	3
60	78·80	61·57	157·60	123·13	236·40	184·70	315·20	246·26	394·00	307·83	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		

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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	479·18	361·09	559·04	421·27	638·90	481·45	718·77	541·63	798·63	601·81	60
3	478·86	361·51	558·67	421·76	638·48	482·01	718·30	542·26	798·11	602·51	57
6	478·55	361·92	558·30	422·24	638·06	482·57	717·82	542·89	797·58	603·21	54
9	478·23	362·34	557·94	422·73	637·64	483·12	717·35	543·52	797·06	603·91	51
12	477·91	362·76	557·57	423·22	637·22	483·68	716·87	544·14	796·53	604·60	48
15	477·60	363·18	557·20	423·71	636·80	484·23	716·40	544·77	796·00	605·30	45
18	477·28	363·59	556·83	424·19	636·37	484·79	715·92	545·39	795·47	605·99	42
21	476·96	364·01	556·46	424·67	635·95	485·35	715·45	546·02	794·94	606·68	39
24	476·64	364·42	556·09	425·16	635·53	485·90	714·97	546·64	794·41	607·37	36
27	476·33	364·84	555·72	425·64	635·11	486·46	714·49	547·26	793·88	608·06	33
30	476·01	365·25	555·34	426·13	634·68	487·01	714·01	547·88	793·35	608·76	30
33	475·69	365·67	554·97	426·62	634·26	487·57	713·54	548·50	792·82	609·45	27
36	475·37	366·08	554·60	427·10	633·83	488·12	713·06	549·13	792·29	610·14	24
39	475·05	366·50	554·23	427·59	633·40	488·67	712·58	549·75	791·76	610·83	21
42	474·73	366·91	553·85	428·07	632·97	489·22	712·10	550·37	791·22	611·52	18
45	474·41	367·33	553·48	428·55	632·55	489·77	711·62	550·99	790·69	612·21	15
48	474·09	367·74	553·10	429·03	632·12	490·32	711·14	551·62	790·15	612·90	12
51	473·77	368·15	552·73	429·52	631·69	490·87	710·66	552·24	789·62	613·59	9
54	473·45	368·57	552·35	430·00	631·26	491·42	710·18	552·85	789·08	614·28	6
57	473·13	368·99	551·98	430·48	630·83	491·98	709·69	553·47	788·55	614·97	3
60	472·80	369·40	551·60	430·96	630·40	492·53	709·21	554·09	788·01	615·66	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		

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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	78 80	61·57	157·60	123·13	236·40	184·70	315·20	246·26	394·00	307·83	60
3	78·75	61·63	157·49	123·27	236·24	184·91	314·99	246·53	393·74	308·17	57
6	78·69	61·70	157·38	123·40	236·07	185·11	314·77	246·81	393·47	308·51	54
9	78·64	61·77	157·28	123·54	235·91	185·32	314·56	247·08	393·20	308·85	51
12	78·58	61·84	157·17	123·68	235·75	185·52	314·34	247·36	392·93	309·20	48
15	78·53	61·91	157·06	123·82	235·59	185·73	314·13	247·63	392·66	309·54	45
18	78·48	61·98	156·95	123·95	235·43	185·93	313·91	247·91	392·39	309·89	42
21	78·42	62·05	156·84	124·09	235·27	186·14	313·69	248·18	392·12	310·23	39
24	78·37	62·11	156·73	124·23	235·10	186·34	313·47	248·46	391·85	310·57	36
27	78·31	62·18	156·63	124·36	234·94	186·55	313·26	248·73	391·58	310·91	33
30	78·26	62·25	156·52	124·50	234·78	186·75	313·04	249·00	391·30	311·25	30
33	78·21	62·32	156·41	124·64	234·62	186·96	312·82	249·28	391·03	311·59	27
36	78·15	62·39	156·30	124·77	234·45	187·16	312·60	249·55	390·76	311·94	24
39	78·10	62·46	156·19	124·91	234·29	187·37	312·39	249·83	390·49	312·28	21
42	78·04	62·52	156·08	125·04	234·13	187·57	312·17	250·10	390·21	312·62	18
45	77·99	62·59	155·97	125·18	233·97	187·78	311·95	250·37	389·94	312·96	15
48	77·93	62·66	155·86	125·32	233·80	187·98	311·73	250·64	389·67	313·30	12
51	77·88	62·73	155·75	125·46	233·64	188·19	311·51	250·92	389·40	313·64	9
54	77·82	62·79	155·64	125·59	233·47	188·39	311·29	251·19	389·12	313·98	6
57	77·77	62·86	155·53	125·73	233·31	188·59	311·07	251·43	388·85	314·32	3
60	77·71	62·93	155·42	125·86	233·14	188·80	310·85	251·73	388·57	314·66	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	472·80	369·40	551·60	430·96	630·40	492·53	709·21	554·09	788·01	615·66	60
3	472·48	369·81	551·23	431·44	629·97	493·08	708·73	554·71	787·47	616·35	57
6	472·16	370·22	550·85	431·92	629·54	493·62	708·24	555·33	786·93	617·03	54
9	471·84	370·63	550·48	432·40	629·11	494·17	707·76	555·95	786·39	617·72	51
12	471·51	371·04	550·10	432·88	628·68	494·72	707·27	556·56	785·85	618·41	48
15	471·19	371·45	549·72	433·36	628·25	495·27	706·79	557·18	785·31	619·10	45
18	470·86	371·86	549·34	433·84	627·82	495·82	706·30	557·80	784·77	619·78	42
21	470·54	372·27	548·96	434·32	627·39	496·37	705·81	558·42	784·23	620·46	39
24	470·21	372·68	548·58	434·80	626·95	496·92	705·32	559·03	783·69	621·14	36
27	469·89	373·09	548·20	435·28	626·52	497·47	704·83	559·65	783·15	621·82	33
30	469·56	373·50	547·82	435·75	626·08	498·01	704·34	560·26	782·60	622·51	30
33	469·24	373·91	547·44	436·23	625·65	498·56	703·85	560·88	782·06	623·19	27
36	468·91	374·32	547·06	436·71	625·21	499·10	703·36	561·49	781·52	623·88	24
39	468·59	374·73	546·68	437·19	624·78	499·65	702·87	562·11	780·98	624·56	21
42	468·26	375·14	546·30	437·67	624·34	500·19	702·38	562·72	780·43	625·24	18
45	467·93	375·55	545·92	438·14	623·91	500·74	701·89	563·33	779·88	625·92	15
48	467·60	375·96	545·53	438·62	623·47	501·28	701·40	563·94	779·33	626·60	12
51	467·27	376·37	545·15	439·10	623·03	501·83	700·91	564·55	778·79	627·28	9
54	466·94	376·77	544·77	439·57	622·59	502·37	700·42	565·16	778·24	627·96	6
57	466·61	377·18	544·39	440·05	622·15	502·91	699·93	565·77	777·69	628·64	3
60	466·28	377·59	544·00	440·52	621·71	503·45	699·43	566·38	777·14	629·32	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	77·71	62·93	155·42	125·86	233·14	188·80	310·85	251·73	388·57	314·66	60
3	77·66	63·00	155·31	126·00	232·98	189·00	310·63	252·00	388·30	315·00	57
6	77·60	63·07	155·20	126·13	232·81	189·20	310·41	252·27	388·02	315·34	54
9	77·55	63·13	155·09	126·27	232·65	189·41	310·19	252·54	387·75	315·67	51
12	77·49	63·20	154·98	126·40	232·48	189·61	309·97	252·81	387·47	316·01	48
15	77·44	63·27	154·87	126·54	232·32	189·81	309·75	253·08	387·20	316·35	45
18	77·38	63·34	154·76	126·67	232·15	190·01	309·53	253·35	386·92	316·69	42
21	77·33	63·40	154·65	126·81	231·99	190·21	309·31	253·62	386·64	317·03	39
24	77·27	63·47	154·54	126·94	231·82	190·42	309·09	253·89	386·36	317·36	36
27	77·22	63·54	154·43	127·08	231·65	190·62	308·87	254·16	386·09	317·70	33
30	77·16	63·61	154·32	127·21	231·48	190·82	308·65	254·43	385·81	318·03	30
33	77·11	63·67	154·21	127·35	231·32	191·02	308·43	254·70	385·54	318·37	27
36	77·05	63·74	154·10	127·48	231·15	191·22	308·20	254·97	385·25	318·71	24
39	77·00	63·81	153·99	127·62	230·99	191·42	307·98	255·24	384·98	319·04	21
42	76·94	63·88	153·88	127·75	230·82	191·63	307·76	255·50	384·70	319·38	18
45	76·88	63·94	153·77	127·89	230·65	191·83	307·54	255·77	384·42	319·72	15
48	76·83	64·01	153·65	128·02	230·48	192·03	307·31	256·04	384·14	320·05	12
51	76·77	64·08	153·54	128·16	230·32	192·23	307·09	256·31	383·86	320·39	9
54	76·72	64·14	153·43	128·29	230·15	192·43	306·86	256·58	383·58	320·73	6
57	76·66	64·21	153·32	128·42	229·98	192·63	306·64	256·85	383·30	321·06	3
60	76·60	64·28	153·21	128·55	229·81	192·83	306·41	257·11	383·02	321·39	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	466·28	377·59	544·00	440·52	621·71	503·45	699·43	566·38	777·14	629·32	60
3	465·95	378·00	543·62	441·00	621·27	504·00	698·94	567·00	776·59	630·00	57
6	465·62	378·40	543·23	441·47	620·83	504·54	698·44	567·61	776·04	630·67	54
9	465·29	378·81	542·85	441·95	620·39	505·09	697·95	568·21	775·49	631·35	51
12	464·96	379·21	542·46	442·42	619·95	505·63	697·45	568·82	774·94	632·03	48
15	464·63	379·61	542·08	442·90	619·51	506·17	696·95	569·43	774·39	632·70	45
18	464·30	380·02	541·69	443·37	619·07	506·71	696·45	570·04	773·84	633·37	42
21	463·97	380·42	541·30	443·84	618·63	507·25	695·96	570·65	773·29	634·05	39
24	463·64	380·83	540·91	444·31	618·18	507·79	695·46	571·26	772·73	634·73	36
27	463·31	381·23	540·53	444·78	617·74	508·33	694·96	571·87	772·18	635·40	33
30	462·97	381·64	540·14	445·25	617·30	508·86	694·46	572·47	771·62	636·07	30
33	462·64	382·04	539·75	445·72	616·86	509·40	693·96	573·07	771·07	636·75	27
36	462·30	382·45	539·36	446·19	616·41	509·94	693·46	573·68	770·51	637·42	24
39	461·97	382·85	538·97	446·66	615·97	510·48	692·96	574·28	769·96	638·09	21
42	461·64	383·26	538·58	447·13	615·52	511·02	692·46	574·89	769·40	638·76	18
45	461·30	383·66	538·19	447·60	615·07	511·56	691·96	575·49	768·84	639·43	15
48	460·96	384·07	537·80	448·07	614·62	512·07	691·46	576·10	768·28	640·10	12
51	460·63	384·47	537·41	448·54	614·18	512·62	690·96	576·70	767·72	640·77	9
54	460·29	384·87	537·01	449·01	613·73	513·16	690·45	577·30	767·16	641·44	6
57	459·96	385·27	536·62	449·48	613·28	513·69	689·95	577·90	766·60	642·11	3
60	459·62	385·67	536·23	449·95	612·83	514·23	689·44	578·51	766·04	642·78	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	76·60	64·28	153·21	128·55	229·81	192·83	306·41	257·11	383·02	321·39	60
3	76·55	64·34	153·10	128·68	229·64	193·03	306·19	257·37	382·74	321·72	57
6	76·49	64·41	152·98	128·82	229·47	193·23	305·96	257·64	382·46	322·06	54
9	76·44	64·48	152·87	128·95	229·30	193·43	305·74	257·91	382·18	322·39	51
12	76·38	64·54	152·75	129·09	229·13	193·63	305·51	258·18	381·89	322·73	48
15	76·32	64·61	152·64	129·22	228·97	193·83	305·29	258·44	381·61	323·06	45
18	76·27	64·68	152·53	129·35	228·80	194·03	305·06	258·71	381·33	323·39	42
21	76·21	64·75	152·42	129·48	228·63	194·23	304·84	258·97	381·05	323·72	39
24	76·15	64·81	152·30	129·62	228·46	194·43	304·61	259·24	380·77	324·06	36
27	76·10	64·88	152·19	129·75	228·29	194·63	304·39	259·50	380·49	324·39	33
30	76·04	64·95	152·08	129·88	228·12	194·83	304·16	259·77	380·20	324·72	30
33	75·98	65·01	151·97	130·01	227·95	195·03	303·94	260·04	379·92	325·05	27
36	75·93	65·08	151·85	130·15	227·78	195·23	303·71	260·30	379·63	325·38	24
39	75·87	65·14	151·74	130·28	227·61	195·43	303·48	260·57	379·35	325·71	21
42	75·81	65·21	151·62	130·42	227·44	195·63	303·25	260·84	379·06	326·04	18
45	75·76	65·28	151·51	130·55	227·27	195·83	303·03	261·10	378·78	326·37	15
48	75·70	65·34	151·40	130·68	227·09	196·02	302·80	261·37	378·49	326·71	12
51	75·64	65·41	151·29	130·81	226·92	196·22	302·57	261·63	378·21	327·04	9
54	75·58	65·47	151·17	130·94	226·75	196·42	302·34	261·89	377·92	327·37	6
57	75·53	65·54	151·06	131·08	226·58	196·62	302·11	262·16	377·64	327·70	3
60	75·47	65·61	150·94	131·21	226·41	196·81	301·88	262·42	377·35	328·03	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	459·62	385·67	536·23	449·95	612·83	514·23	689·44	578·51	766·04	642·78	60
3	459·29	386·07	535·84	450·42	612·38	514·76	688·93	579·11	765·48	643·45	57
6	458·95	386·47	535·44	450·88	611·93	515·30	688·42	579·71	764·92	644·12	54
9	458·61	386·87	535·05	451·35	611·48	515·83	687·92	580·31	764·36	644·79	51
12	458·27	387·27	534·65	451·82	611·03	516·36	687·41	580·91	763·79	645·45	48
15	457·94	387·67	534·26	452·29	610·58	516·89	686·91	581·51	763·23	646·12	45
18	457·60	388·07	533·86	452·75	610·13	517·43	686·40	582·11	762·66	646·79	42
21	457·26	388·47	533·47	453·22	609·68	517·96	685·89	582·71	762·10	647·46	39
24	456·92	388·87	533·07	453·68	609·23	518·49	685·38	583·31	761·53	648·12	36
27	456·58	389·27	532·68	454·15	608·78	519·02	684·87	583·91	760·97	648·79	33
30	456·24	389·67	532·28	454·61	608·32	519·56	684·36	584·50	760·40	649·45	30
33	455·90	390·06	531·89	455·08	607·87	520·09	683·85	585·10	759·84	650·11	27
36	455·56	390·46	531·49	455·54	607·42	520·62	683·34	585·70	759·27	650·77	24
39	455·22	390·86	531·10	456·01	606·97	521·15	682·83	586·29	758·70	651·43	21
42	454·88	391·26	530·70	456·47	606·51	521·68	682·32	586·89	758·13	652·10	18
45	454·54	391·66	530·30	456·93	606·06	522·21	681·81	587·48	757·56	652·76	15
48	454·19	392·05	529·90	457·39	605·60	522·73	681·30	588·08	756·99	653·42	12
51	453·85	392·45	529·50	457·85	605·15	523·26	680·79	588·67	756·42	654·08	9
54	453·51	392·84	529·10	458·32	604·69	523·79	680·27	589·27	755·85	654·74	6
57	453·17	393·24	528·70	458·78	604·23	524·32	679·76	589·86	755·28	655·40	3
60	452·82	393·63	528·30	459·24	603·77	524·84	679·24	590·45	754·71	656·06	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	75·47	65·61	150·94	131·21	226·41	196·81	301·88	262·42	377·35	328·03	60
3	75·41	65·67	150·83	131·34	226·24	197·01	301·65	262·68	377·07	328·36	57
6	75·36	65·74	150·71	131·47	226·06	197·21	301·42	262·95	376·78	328·69	54
9	75·30	65·80	150·60	131·60	225·89	197·41	301·19	263·21	376·49	329·01	51
12	75·24	65·87	150·48	131·73	225·72	197·60	300·96	263·47	376·20	329·34	48
15	75·19	65·93	150·37	131·86	225·55	197·80	300·73	263·73	375·92	329·67	45
18	75·13	66·00	150·25	132·00	225·38	198·00	300·50	264·00	375·63	330·00	42
21	75·07	66·07	150·14	132·13	225·21	198·20	300·27	264·26	375·34	330·33	39
24	75·01	66·13	150·02	132·26	225·03	198·39	300·04	264·52	375·05	330·65	36
27	74·95	66·20	149·91	132·39	224·86	198·59	299·81	264·78	374·77	330·98	33
30	74·89	66·26	149·79	132·52	224·68	198·78	299·58	265·04	374·48	331·31	30
33	74·84	66·33	149·68	132·65	224·51	198·98	299·35	265·30	374·19	331·64	27
36	74·78	66·39	149·56	132·78	224·34	199·17	299·12	265·57	373·90	331·96	24
39	74·72	66·46	149·44	132·91	224·17	199·37	298·89	265·83	373·61	332·29	21
42	74·66	66·52	149·32	133·04	223·99	199·56	298·65	266·09	373·32	332·61	18
45	74·60	66·59	149·21	133·17	223·82	199·76	298·42	266·35	373·03	332·94	15
48	74·55	66·65	149·09	133·30	223·64	199·95	298·19	266·61	372·74	333·26	12
51	74·49	66·72	148·98	133·43	223·47	200·15	297·96	266·87	372·45	333·59	9
54	74·43	66·78	148·86	133·56	223·29	200·34	297·72	267·13	372·15	333·91	6
57	74·37	66·85	148·74	133·69	223·12	200·54	297·49	267·39	371·86	334·24	3
60	74·31	66·91	148·62	133·82	222·94	200·73	297·26	267·65	371·57	334·56	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	452·82	393·63	528·30	459·24	603·77	524·84	679·24	590·45	754·71	656·06	60
3	452·48	394·02	527·90	459·70	603·31	525·37	678·72	591·04	754·14	656·72	57
6	452·13	394·42	527·49	460·16	602·85	525·90	678·20	591·64	753·56	657·37	54
9	451·79	394·81	527·09	460·62	602·39	526·43	677·69	592·23	752·99	658·03	51
12	451·44	395·21	526·69	461·08	601·93	526·95	677·17	592·82	752·41	658·68	48
15	451·10	395·60	526·29	461·54	601·47	527·48	676·65	593·41	751·84	659·34	45
18	450·75	396·00	525·88	462·00	601·01	528·00	676·13	594·00	751·26	660·00	42
21	450·41	396·39	525·48	462·46	600·55	528·52	675·62	594·59	750·69	660·66	39
24	450·06	396·79	525·08	462·91	600·09	529·05	675·10	595·18	750·11	661·31	36
27	449·72	397·18	524·68	463·37	599·63	529·57	674·58	595·77	749·53	661·97	33
30	449·37	397·57	524·27	463·83	599·16	530·09	674·06	596·36	748·95	662·62	30
33	449·03	397·96	523·87	464·29	598·70	530·62	673·54	596·94	748·37	663·27	27
36	448·68	398·35	523·46	464·74	598·23	531·14	673·02	597·53	747·79	663·92	24
39	448·33	398·74	523·06	465·20	597·77	531·66	672·50	598·12	747·21	664·57	21
42	447·98	399·13	522·65	465·66	597·31	532·18	671·97	598·70	746·63	665·23	18
45	447·63	399·52	522·24	466·12	596·85	532·70	671·45	599·29	746·05	665·88	15
48	447·28	399·92	521·83	466·57	596·38	533·22	670·92	599·88	745·47	666·53	12
51	446·93	400·31	521·42	467·03	595·92	533·74	670·40	600·47	744·89	667·18	9
54	446·58	400·70	521·01	467·48	595·45	534·26	669·88	601·05	744·31	667·83	6
57	446·23	401·09	520·61	467·94	594·98	534·78	669·36	601·63	743·73	668·48	3
60	445·88	401·48	520·20	468·39	594·51	535·30	668·83	602·21	743·14	669·13	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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0	74·31	66·91	148·62	133·82	222·94	200·73	297·26	267·65	371·57	334·56	60
3	74·26	66·98	148·51	133·95	222·77	200·92	297·03	267·91	371·28	334·88	57
6	74·20	67·04	148·39	134·08	222·59	201·12	296·79	268·17	370·98	335·21	54
9	74·14	67·11	148·28	134·21	222·42	201·31	296·56	268·43	370·69	335·53	51
12	74·08	67·17	148·16	134·34	222·24	201·51	296·32	268·68	370·40	335·86	48
15	74·02	67·24	148·04	134·47	222·06	201·70	296·09	268·94	370·11	336·18	45
18	73·96	67·30	147·92	134·60	221·88	201·90	295·85	269·20	369·81	336·50	42
21	73·90	67·37	147·81	134·73	221·71	202·09	295·62	269·46	369·52	336·82	39
24	73·84	67·43	147·69	134·86	221·53	202·29	295·38	269·72	369·23	337·15	36
27	73·79	67·49	147·57	134·99	221·36	202·48	295·15	269·98	368·94	337·47	33
30	73·73	67·56	147·45	135·11	221·18	202·67	294·91	270·23	368·64	337·79	30
33	73·67	67·62	147·34	135·24	221·00	202·86	294·68	270·49	368·35	338·11	27
36	73·61	67·69	147·22	135·37	220·83	203·06	294·44	270·75	368·05	338·43	24
39	73·55	67·75	147·10	135·50	220·65	203·25	294·20	271·01	367·75	338·75	21
42	73·49	67·82	146·98	135·63	220·47	203·44	293·96	271·26	367·46	339·08	18
45	73·43	67·88	146·86	135·76	220·30	203·63	293·73	271·52	367·16	339·40	15
48	73·37	67·94	146·74	135·88	220·12	203·83	293·49	271·77	366·86	339·72	12
51	73·31	68·01	146·63	136·01	219·94	204·02	293·25	272·03	366·57	340·04	9
54	73·25	68·07	146·51	136·14	219·76	204·21	293·01	272·28	366·27	340·36	6
57	73·19	68·14	146·39	136·27	219·58	204·40	292·78	272·54	365·97	340·68	3
60	73·13	68·20	146·27	136·40	219·40	204·60	292·54	272·80	365·67	341·00	0
	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Base. Dep.	Per. Lat.	Minutes.
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	445·88	401·48	520·20	468·39	594·51	535·30	668·83	602·21	743·14	669·13	60
3	445·53	401·87	519·79	468·84	594·05	535·82	668·31	602·80	742·56	669·78	57
6	445·18	402·25	519·38	469·29	593·58	536·34	667·78	603·38	741·97	670·42	54
9	444·83	402·64	518·97	469·75	593·11	536·86	667·25	603·96	741·37	671·07	51
12	444·48	403·03	518·56	470·20	592·64	537·37	666·72	604·55	740·80	671·72	48
15	444·13	403·42	518·15	470·65	592·17	537·89	666·20	605·13	740·22	672·37	45
18	443·78	403·80	517·74	471·10	591·70	538·41	665·67	605·71	739·63	673·01	42
21	443·43	404·19	517·33	471·55	591·23	538·93	665·14	606·29	739·04	673·66	39
24	443·07	404·58	516·92	472·01	590·76	539·44	664·61	606·87	738·45	674·30	36
27	442·72	404·97	516·51	472·46	590·29	539·96	664·08	607·45	737·86	674·95	33
30	442·36	405·35	516·09	472·91	589·82	540·47	663·55	608·03	737·27	675·59	30
33	442·01	405·74	515·68	473·36	589·35	540·99	663·02	608·61	736·68	676·24	27
36	441·65	406·12	515·27	473·81	588·87	541·50	662·49	609·19	736·09	676·88	24
39	441·30	406·51	514·86	474·26	588·40	542·02	661·95	609·77	735·50	677·52	21
42	440·94	406·89	514·44	474·71	587·93	542·53	661·42	610·34	734·91	678·16	18
45	440·59	407·28	514·03	475·16	587·46	543·04	660·89	610·92	734·32	678·80	15
48	440·23	407·66	513·61	475·60	586·98	543·55	660·35	611·49	733·73	679·44	12
51	439·88	408·05	513·20	476·05	586·51	544·06	659·82	612·07	733·14	680·08	9
54	439·52	408·43	512·78	476·50	586·03	544·57	659·28	612·65	732·54	680·72	6
57	439·17	408·82	512·36	476·95	585·56	545·08	658·75	613·22	731·95	681·36	3
60	438·81	409·20	511·94	477·40	585·08	545·60	658·21	613·80	731·35	682·00	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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Minutes.	Dist. 100.		Dist. 200.		Dist. 300.		Dist. 400.		Dist. 500.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	73·13	68·20	146·27	136·40	219·40	204·60	292·54	272·80	365·67	341·00	60
3	73·08	68·26	146·15	136·53	219·22	204·79	292·30	273·05	365·37	341·32	57
6	73·02	68·33	146·03	136·65	219·04	204·98	292·06	273·30	365·07	341·63	54
9	72·96	68·39	145·91	136·78	218·87	205·17	291·82	273·56	364·78	341·95	51
12	72·89	68·45	145·79	136·90	218·69	205·36	291·58	273·81	364·48	342·27	48
15	72·84	68·52	145·67	137·03	218·51	205·55	291·34	274·07	364·18	342·59	45
18	72·78	68·58	145·55	137·16	218·33	205·74	291·10	274·32	363·88	342·91	42
21	72·72	68·64	145·43	137·29	218·15	205·93	290·86	274·58	363·58	343·22	39
24	72·66	68·71	145·31	137·41	217·97	206·12	290·62	274·83	363·28	343·54	36
27	72·60	68·77	145·19	137·54	217·79	206·31	290·38	275·09	362·98	343·86	33
30	72·54	68·83	145·07	137·67	217·61	206·50	290·14	275·34	362·68	344·18	30
33	72·48	68·90	144·95	137·80	217·43	206·69	289·90	275·60	362·38	344·49	27
36	72·42	68·96	144·83	137·92	217·25	206·88	289·66	275·85	362·08	344·81	24
39	72·36	69·02	144·71	138·05	217·07	207·07	289·42	276·10	361·78	345·12	21
42	72·30	69·09	144·59	138·17	216·89	207·26	289·18	276·35	361·48	345·44	18
45	72·24	69·15	144·47	138·30	216·71	207·45	288·94	276·60	361·18	345·75	15
48	72·18	69·21	144·35	138·42	216·52	207·64	288·70	276·85	360·88	346·07	12
51	72·12	69·28	144·23	138·55	216·34	207·83	288·46	277·10	360·58	346·39	9
54	72·06	69·34	144·11	138·68	216·16	208·02	288·22	277·36	360·27	346·70	6
57	72·00	69·40	143·99	138·81	215·98	208·21	287·98	277·61	359·97	347·02	3
60	71·93	69·47	143·86	138·93	215·80	208·40	287·73	277·86	359·67	347·33	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	438·81	409·20	511·94	477·40	585·08	545·60	658·21	613·80	731·35	682·00	60
3	438·45	409·58	511·53	477·85	584·61	546·11	657·68	614·37	730·76	682·64	57
6	438·09	409·96	511·11	478·29	584·13	546·61	657·14	614·94	730·16	683·27	54
9	437·74	410·34	510·69	478·74	583·65	547·12	656·61	615·51	729·56	683·91	51
12	437·38	410·72	510·27	479·18	583·17	547·63	656·07	616·09	728·96	684·54	48
15	437·02	411·10	509·86	479·63	582·69	548·14	655·53	616·66	728·37	685·18	45
18	436·66	411·49	509·44	480·07	582·21	548·65	654·99	617·23	727·77	685·82	42
21	436·30	411·87	509·02	480·52	581·73	549·16	654·45	617·80	727·17	686·45	39
24	435·94	412·25	508·60	480·96	581·25	549·67	653·91	618·38	726·57	687·08	36
27	435·58	412·63	508·18	481·41	580·77	550·18	653·37	618·95	725·97	687·71	33
30	435·22	413·01	507·76	481·85	580·29	550·68	652·83	619·52	725·37	688·35	30
33	434·86	413·39	507·34	482·29	579·81	551·19	652·29	620·09	724·77	688·98	27
36	434·50	413·77	506·92	482·73	579·33	551·69	651·75	620·66	724·17	689·62	24
39	434·14	414·15	506·50	483·17	578·85	552·20	651·21	621·23	723·57	690·25	21
42	433·78	414·53	506·07	483·61	578·37	552·70	650·67	621·79	722·96	690·88	18
45	433·42	414·90	505·65	484·05	577·89	553·21	650·13	622·36	722·36	691·51	15
48	433·05	415·28	505·23	484·49	577·40	553·71	649·58	622·93	721·75	692·14	12
51	432·69	415·66	504·81	484·93	576·92	554·22	649·04	623·49	721·15	692·77	9
54	432·33	416·04	504·38	485·38	576·44	554·72	648·49	624·06	720·55	693·40	6
57	431·97	416·42	503·96	485·82	575·96	555·22	647·95	624·63	719·95	694·03	3
60	431·60	416·79	503·53	486·26	575·47	555·72	647·40	625·19	719·34	694·66	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	71·93	69·47	143·86	138·93	215·80	208·40	287·73	277·86	359·67	347·33	60
3	71·87	69·53	143·74	139·05	215·62	208·59	287·49	278·11	359·37	347·64	57
6	71·81	69·59	143·62	139·18	215·43	208·77	287·25	278·36	359·06	347·95	54
9	71·75	69·65	143·50	139·30	215·25	208·96	287·00	278·61	358·76	348·27	51
12	71·69	69·72	143·38	139·43	215·07	209·15	286·76	278·86	358·45	348·58	48
15	71·63	69·78	143·26	139·55	214·89	209·34	286·52	279·11	358·15	348·90	45
18	71·57	69·84	143·14	139·68	214·70	209·52	286·27	279·36	357·84	349·21	42
21	71·51	69·90	143·02	139·80	214·52	209·71	286·03	279·61	357·54	349·52	39
24	71·45	69·97	142·89	139·93	214·34	209·89	285·78	279·86	357·23	349·83	36
27	71·39	70·03	142·77	140·05	214·16	210·08	285·54	280·11	356·93	350·14	33
30	71·33	70·09	142·65	140·18	213·97	210·27	285·30	280·36	356·62	350·45	30
33	71·26	70·15	142·53	140·30	213·79	210·46	285·06	280·61	356·32	350·76	27
36	71·20	70·21	142·40	140·43	213·60	210·64	284·81	280·86	356·01	351·07	24
39	71·14	70·28	142·28	140·55	213·42	210·83	284·57	281·11	355·71	351·38	21
42	71·08	70·34	142·16	140·68	213·24	211·01	284·32	281·35	355·40	351·69	18
45	71·02	70·40	142·04	140·80	213·06	211·20	284·07	281·60	355·09	352·00	15
48	70·96	70·46	141·91	140·92	212·87	211·39	283·82	281·85	354·78	352·31	12
51	70·90	70·52	141·79	141·05	212·69	211·58	283·58	282·10	354·48	352·62	9
54	70·83	70·59	141·66	141·17	212·50	211·76	283·33	282·34	354·17	352·93	6
57	70·77	70·65	141·54	141·30	212·32	211·95	283·09	282·59	353·86	353·24	3
60	70·71	70·71	141·42	141·42	212·13	212·13	282·84	282·84	353·55	353·55	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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Minutes.	Dist. 600.		Dist. 700.		Dist. 800.		Dist. 900.		Dist. 1000.		
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	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	
0	431·60	416·79	503·53	486·26	575·47	555·72	647·40	625·19	719·34	694·66	60
3	431·24	417·16	503·11	486·70	574·99	556·22	646·86	625·75	718·73	695·29	57
6	430·87	417·54	502·68	487·13	574·50	556·72	646·31	626·32	718·12	695·91	54
9	430·51	417·91	502·26	487·57	574·02	557·22	645·77	626·88	717·52	696·53	51
12	430·14	418·29	501·83	488·01	573·53	557·73	645·22	627·44	716·91	697·16	48
15	429·78	418·66	501·41	488·45	573·04	558·23	644·67	628·00	716·30	697·79	45
18	429·41	419·04	500·98	488·89	572·55	558·73	644·12	628·57	715·69	698·41	42
21	429·05	419·42	500·56	489·33	572·06	559·23	643·57	629·13	715·08	699·03	39
24	428·68	419·79	500·13	489·76	571·57	559·73	643·02	629·69	714·47	699·66	36
27	428·32	420·17	499·70	490·20	571·09	560·23	642·47	630·25	713·86	700·29	33
30	427·95	420·54	499·27	490·63	570·60	560·72	641·92	630·81	713·25	700·91	30
33	427·58	420·92	498·84	491·07	570·11	561·22	641·37	631·37	712·64	701·53	27
36	427·21	421·29	498·41	491·50	569·62	561·72	640·82	631·93	712·02	702·15	24
39	426·85	421·67	497·98	491·94	569·13	562·22	640·27	632·49	711·41	702·77	21
42	426·48	422·04	497·55	492·37	568·64	562·71	639·72	633·05	710·80	703·39	18
45	426·11	422·41	497·12	492·81	568·15	563·21	639·17	633·61	710·19	704·01	15
48	425·74	422·78	496·69	493·24	567·65	563·70	638·61	634·17	709·57	704·63	12
51	425·37	423·15	496·26	493·68	567·16	564·20	638·06	634·73	708·96	705·25	9
54	425·00	423·52	495·83	494·11	566·67	564·69	637·50	635·28	708·34	705·87	6
57	424·63	423·89	495·40	494·54	566·17	565·19	636·95	635·84	707·72	706·48	3
60	424·26	424·26	494·97	494·97	565·68	565·68	636·39	636·39	707·10	707·10	0
	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Base.	Per.	Minutes.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
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APPENDIX.

MAGNETIC SURVEYING AND ANGULAR SURVEYING.

CHAPTER I.

GENERAL VIEW OF MINING SURVEYING.

In considering this subject we have to bear in mind that the value of the magnetic needle in mining surveying consists in that instrument affording a means of determining the relative direction of different lines. This relative direction is generally obtained with approximate accuracy only, but, assuming the needle to be in a normal condition, the degree of approximation which may be insured depends chiefly upon the skill and care of the surveyor, and in a secondary degree upon the surrounding circumstances of position and extraneous diverting influences. If there are no obstacles in the way of procuring these relative bearings by plain angular measurements, and the nature of the work requires that the highest degree of attainable accuracy should be insured, then there can be no doubt that the magnetic needle should be dispensed with, and the work performed without its aid; but this will not always be practicable.

In indicating different instances in the operations of the surveyor we may first take the cases of simple surface surveys of estates without reference to any minerals, and of surface engineering works in general. In these classes of work there can scarcely be conceived a combination of conditions under which the use of the magnetic needle for the mere purposes of the survey becomes indispensable, because all lines that are accessible to the surveyor for the employment of the Theodolite for one class of readings, such as magnetic, would be equally open to angular readings, and therefore the latter would in such cases naturally have the preference. But when

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the surface survey has reference to mineral property to be developed, and underground workings of minerals have to be delineated upon the plan, the accurate laying down of the then magnetic meridian upon it becomes a matter of great importance in view to its subsequent employment in laying down the undergound surveys ; but this circumstance does not render the employment of the needle in making the surface survey necessary, nor under all circumstances preferable. As a rule the surface survey will be best carried out if conducted in the manner indicated in Chapter XI. of the "Mineral Surveyor's and Valuer's Guide," or some modification of it as circumstances may require.

In order to take such steps as shall contribute to the laying down of an accurate magnetic meridian upon the plan of the surface, two of the longest lines of the surface survey should be selected for the operation, and setting up the Theodolite or other instrument suitable for exact magnetic readings at the junction of the two lines, the surveyor should direct his assistant to set up about four ranging poles in accurate alignment in each of the lines, and at some 40 yards apart, and when this has been done carefully take the magnetic reading of each of these lines at their intersection and note them, after which remove the instrument and set up in its place a pole bearing a flag to distinguish it from the others ; then, taking the instrument to each of the positions in succession marked by the poles, and setting it up and adjusting successively, the surveyor will fix the needle to the zero of the dial-box, and take the two series of bearings of the flag-pole—reading all the angles off to minutes, and adding each to its corresponding reading previously taken. If the readings of each line are thus entered in a separate series and the mean of each computed, the divergence of the two lines from each other, as indicated by the magnetic readings, can then be ascetained from them. If this divergence is then compared with the actual divergence, to be carefully ascertained by a plain angular measurement with the instrument, the identity of these divergences or otherwise will indicate the degree of accuracy with which the needle bearings, and through them the magnetic meridian (or its now known

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divergence from either of these lines), have been obtained ; and if the magnetic meridian be then laid down from the longest of these two lines, supposed to be already laid upon the plan or drawing paper, giving the divergence from it which the foregoing averages indicate, the said meridian will have been obtained with sufficient accuracy for all *practical purposes of surveying*, and may be used without hesitation for laying down magnetic bearings taken at the time or within a short period of it. If the survey made is merely for a plan of a route proposed for a railway or of some other engineering work, and having no reference to minerals to be worked under the surface, a single observation of the magnetic bearing of some one of the base lines will in general be sufficiently accurate for the marking of the magnetic meridian on such plan, if it should be deemed necessary to indicate it.

The operation of giving an accurate direction upon the plan to the lines of the subterranean survey so that they may conform with the true direction of the drivages is a matter that requires great care and consideration, but its difficulties have occasionally been magnified. We refer now more particularly to the case where minerals are obtained by means of a shaft, and not by an open level or drift. In the latter case it is easy to extend a series of angular observations, in continuation of the surface lines, into the mine as far as may be necessary, and to lay down the underground workings accurately from it; but in the former case the shaft intervenes, and the plotting operation is in consequence made to depend on other expedients.

Different ways of connecting a surface line with lines at the bottom of the shaft have been proposed, such as extending one of the surface lines across the top of the shaft, and then dropping two plummets laid accurately in its direction from the surface to the bottom of the shaft, and as far apart as the diameter of the shaft admits of, from which plummets at the bottom of the shaft the same surface line may be reproduced in direction, and from it a series of lines and angles extended into the workings of the mine in the operation of the survey. Another plan that has been advocated is to fix the instrument over the shaft in such a position that the direction of a surface line can be

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observed, and with the instrument so fixed in that alignment turn the telescope down so that two lights may be observed and adjusted in the same direction at the shaft bottom. Another plan has been suggested, that of fixing the instrument in the bottom of the shaft, and turning it into alignment with two objects fixed at the surface of the shaft, and seen in the vertical hair of the telescope, and so arrange a parallelism between a surface and a subterranean line. But it is only the first of these three plans that deserves a moment's notice or consideration; and as regards this particular method, it is doubtless quite applicable and suitable to the laying out of a centre line of a railway tunnel through the working shafts, which are generally comparatively shallow, but is not suitable, or only to a very limited degree indeed, to the case of collieries and mines.

In regard to the general operation of mining periodical surveying, we are able to choose between angular surveying without the needle, and general needle surveying, for getting up the surveys; and some persons discard the latter plan, and prefer to work altogether without the needle, in consequence of their belief in the superior accuracy of angular working.

In estimating, then, the comparative accuracy of surveys made with the magnetic needle, and otherwise, we have to take into consideration the conditions under which they are made. In railway tunnels and similar works there is no difficulty in having fixed positions from plummets sent down the working shafts to work from, and the operation in hand is simply that of extending from it either a straight line or a curve, or of working off a straight line, and in these operations a magnetic observation is of no aid or value whatever.

But in mining operations it is generally entirely different, for instead of being able to have fixed points or positions from which to extend forward the lines as the workings progress, the great bulk of mining operations do not admit of fixed points being secured and preserved for this purpose. The extraction of the mineral causes, in the great majority of instances, falling or pressure of the roof and heaving of the floor to such a degree that the possibility of insuring the permanence of fixed posi-

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tions, except in isolated cases, from which to extend the survey at a subsequent period, is certainly the exception and not the rule. But inasmuch as the mining operations of an extensive mine or colliery are carried on at the same time at many places widely separated from each other, it is not a question of one pair of fixed positions from which to work forward the survey, but a pair in each place or small district, or else the labour of each periodical survey on the angular system would become infinite.

But not only would the labour become infinite, but the errors to which the survey would thus be liable would multiply and become much greater than by needle surveying, as in this system without close watchfulness a second source of error comes into play, which might be termed *instrumental.* It would perhaps surprise a great many persons who use the ordinary "miners' dials" generally employed in mining surveying to find how few of them are divided thoroughly accurate, even when supplied by the best makers at a price of from 15 guineas to 20 guineas each. Let two or three or more of such instruments be taken, and set them up in succession in the same position; and after fixing up two ranging poles at about 150 yards off, with a divergence of from 50° to 60° between them, take a series of measurements of the angle subtended by the poles (three or four with each instrument), taking care to turn the body of the instrument round 30° or 40° after each complete observation, and taking the observations *to minutes*, and then compare them with each other. It may be considered almost certain that marked differences will appear not only between different instruments, but in the successive observations with the same instrument, taken as indicated above; and a divergence between the successive observations of the same dial of from 5′ to 8′ will not be uncommon. We have done this with what have been accounted the best miners' dials costing the above amount, and the results have been as above stated; and there is no reason to think that these instruments were not of the average quality supplied for this purpose.

Here, then, we are brought to consider what angular survey-

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ing has to depend upon in part for its reliability ; and when it is borne in mind that in this class of surveying without great care these errors may go on increasing with each angle taken (that they must, if committed, pass into the whole of the subsequent part of the survey), the system is not so secure from error as it would at first sight appear to many to be.

There are, then, these two sources of uncertainty or error that angular surveying, for making up working plans periodically, has to guard against, viz. the unreliability of so-called "fixed points," and imperfect instruments ; and in nearly all the mining operations with which we are acquainted the first of these is a very great obstacle to the employment of the angular system, and the second source of error requires special steps to be taken to guard against the result becoming misleading.

Surveying with the magnetic needle is open to error chiefly from two causes. First, from disregarding the constant change of declination of the magnetic meridian, and so treating it as being an *invariable* line ; and, second, from local attraction or other disturbing causes, which latter may arise either from the quantity of iron or steel that may be within disturbing distance of the instrument, or from earth currents of electricity in the ground, or from both combined.

As regards the first source of error—from change of declination—there are two ways of counteracting it, and of bringing the plotted plan into adjustment with the varying declination. One of these has been described in Chap. VIII. of "Mineral Surveyor's Guide," when treating of the improved dial with its adjusting vernier and zero to represent the line of magnetic meridian, while the ordinary zero of the instrument represents the true meridian. There is another way in which this may be done, which we will now describe.

It is assumed in this case that in working with the ordinary make of instrument the needle is set to the common zero of the dial, and that the angles are then read off to *minutes* from the verniers, both verniers being read and compared by mentally adding 180° to the lesser reading to see if their sum corresponds with the greater reading, which it ought to do if

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the two are accurately read and entered. This should be done throughout the survey, and the annual variation of the magnetic meridian need not in the operation of *making the survey* be taken into account; but in marking off the angles on the plan for plotting the survey a certain number of minutes should be added (*added* at all positions on the earth's surface that have a magnetic *western* declination in process of *reduction*, or *growing less*) to each reading, or angle, depending upon the time that has elapsed since the line of magnetic meridian was *laid down on the plan*, or the year that the line on the plan is intended to represent the meridian for. Inasmuch as the western declination of the magnetic meridian is decreasing at the rate of about 1° in 8 years, the addition to be made to each reading of the dial, before marking off the line with the protractor, should be at this rate, which is an addition of 7½ minutes for each year, or nearly 2 minutes more for each quarterly survey in succession. This does not appear to be a great matter in itself; but those who have had to deal with plans in which the variation has been continuously disregarded and allowed to go on uncorrected over a number of years—thus treating the magnetic meridian as an invariable line—have discovered (unpleasantly sometimes) how widely the workings upon the plan have been found to have strayed away from their true position, for cases of divergence to the extent of 40 yards and upwards to 80 yards are not by any means exaggerated instances known.

To guard against this source of error it is necessary, if the magnetic meridian is to be the working line upon the plan, to make the above correction in the manner indicated (if not corrected as described in Chapter VIII. of "Mineral Surveyor's Guide"); and if this be done, it will afford all the accuracy that is practically attainable so far as correcting for this variation is concerned. It does not, of course, insure the accuracy of anything beyond the subject it immediately refers to, and leaves the matter of the accurate taking and recording of angles untouched; but we believe, after much careful observation and trial, that this system is even preferable to that of seeking to ascertain the variation by means of fixed points on the surface (as is described in Chapter VIII. of "Mineral

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Surveyor's Guide"), and periodical trial with the instrument, because local causes may sometimes operate to disturb the readings of the instrument at any particular time of observation; but the general average for the year will always be left, in the main, untouched, or but slightly affected by casual disturbance, and may be safely and with confidence used for correctional purposes, and it has the further additional advantage of its greater simplicity.

And as regards the errors due to causes of local attraction of the needle, the proposal we occasionally see made in mining literature bearing upon this subject, viz. to remove all fixed ironwork of the tramroads away from where the magnetic needle is to be used, is really so utopian a suggestion that the colliery proprietor or agent, to whom such a request may be made, would probably consider that there was something serious the matter with the judgment of the surveyor who should make such a request in order to enable him to make a survey. The fact is, that were all the iron rails and sleepers of the road, as ordinarily made and employed, drawn up and removed to a distance, the difficulty in this respect would only be slightly mitigated, for experience seems to show unmistakably that the needle is disturbed by currents of electricity constantly passing through the earth, and that these currents are the chief disturbing cause of the local variations which the needle manifests when used in the chambers of the mine. Of course everything of the nature of tools, rails, and sleepers leaning against the side of the drivage, trams, &c., should be removed to a safe distance, but as regards the road such removal is not in the least necessary. It would appear, too, that the variations of the needle from electric currents have a kind of compensating action, and that, in the main, when the observations extend to a considerable number, and are taken over a considerable range of workings, they have a tendency to correct each other, and that the net result of all the angles is not so erroneous as to endanger the accuracy of the true position of the workings upon the plan. This we have repeatedly proved in operations of great importance and considerable magnitude, where the conditions were such as were calculated to afford thoroughly reliable data for arriving at a trustworthy

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estimate of the result. We also think that in the case of the ordinary small rails used in the roads underground, when placed *in situ* in complete contact with the ground, the disturbing tendencies which they may otherwise exercise upon the needle are in a measure counteracted by the interaction between the earth currents of electricity and the magnetism of the needle.

But with the precautions taken as hereinbefore prescribed, and the corrections made systematically, there need be no hesitation, notwithstanding its known liability to variate under normal conditions, in making use of the magnetic needle in getting up the general periodical surveys of mining operations; and in comparison with angular surveying the former is, we consider, often more practicable and certainly not more liable to error for this class of work than the latter system.

While defending, therefore, the magnetic needle from the charge of having now become no longer valuable, we would yet be careful to point out that there are occasions when the competent surveyor will discard it from his service for the time being, and work without it.

We will now particularise a little more minutely the adaptability of "angular" operations, in what may be said to be its own sphere, for accurate working.

It will often occur that two or more drivages locally approximate to each other are required to be driven accurately parallel with each other. The setting of the "points" to guide the miners in the driving of their several workings in the required direction should be done, as regards the second and any subsequent parallel drivage, or even a divergent line, if the angle of divergence is accurately known, without the employment of the needle—however the line of the first and leading drivage may have been laid out; then there is the operation of setting out the line of drivages that are intended for engine planes, inclines, or drifts, that are required to meet accurately; or where one is required to go direct into the alignment of another, whether they are in the same or in different strata of ground, but which are accessible the one from the other without passing through any shaft.

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These are cases in which the survey should be taken and the drivage lines set out without the employment of the needle; and in seeking to escape from the sources of error to which the needle is liable care must be observed not to incur greater errors by the angular operation. As a rule, the employment of a telescope in underground surveying is not desirable nor advantageous, but good plain sights will in that respect afford all needful instrumental accuracy; and, as regards the verniers, it is highly necessary that they should read to minutes and be so employed. Neither is it desirable that the divergence of the lines should be constantly read from the zero of the instrument, but that the "readings" (and especially the duplicate readings from the same station, as is hereinafter described) should be taken from purposely varied parts of the compass-box, in order that any imperfections in the dividing of the instrument may be, so far as is practicable, counteracted and corrected.

CHAPTER II.

MAGNETIC NEEDLE VARIATIONS.

We will now proceed to detail some steps that we have taken, in the course of a considerable practice, to get a tolerably accurate idea of the minute behaviour of the magnetic needle under what may be fairly considered to be the normal conditions surrounding its ordinary employment in the operations of surveying, both underground and on the surface.

The generally received opinion of the action of the magnetic needle when so employed used to be, and we think often still is, that unless diverted by purely local and accidental sources of attraction, and which are, therefore, removable, the needle will adjust itself parallel with the magnetic meridian of the time and of the place in which it is being used, in all positions, and that, consequently, when free to move under such

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conditions, it will, in a series of different positions, maintain a true parallelism.

Several years ago, having occasion to make a survey of a certain colliery, of considerably over a mile in length, and with particular accuracy for a definite purpose, we first made a careful survey with the needle in the ordinary manner—fixing the needle to zero each time and working off the limb and reading the angles to minutes. We next made a check survey over the same lines without using the needle further than to get the magnetic bearing of the first line, so as to insure, as we supposed we should have, the same parallelism of the instrument as before in the previous survey. After the first line in the latter we used the instrument simply as an angleometer, by setting the limb with the precise previous reading back each time upon the last light, and we simply liberated the needle at each station for the purpose of observing its action under those circumstances, and as a sort of check upon the accuracy of the working, as the survey proceeded; but, as the work progressed, to our surprise, we soon found such a marked variation between the parallelism of the needle and of the zero of the instrument, that we came to the conclusion that an error in manipulating the instrument must have been committed. By re-observation of the lines backwards to the starting point, we found that this was not the case, and we then determined to proceed again in the same way throughout the whole length of the survey—in all over forty lines—and particularly to watch the action of the needle in its departure from the line of zero of the instrument. Under this system we found in the majority of the lines in the survey a marked variation of the needle bearing, and in scarcely two successive positions would it assume precisely the same parallelism; sometimes the variation amounted to as much as 2° 30′ on one side of the zero of the instrument, then it would gradually return back again towards the zero line, which it would cover, and then progress to a considerable variation on the other side, thus oscillating to and fro several times over the zero line as the work progressed.

In working out the plan from these two surveys, the successive angles of the second survey were "reduced," taking for

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a base line for reduction the magnetic bearing of the first line, taken as before explained, and both surveys were carefully plotted off the same meridian line and initial position; and the result was that although (as, of course, might naturally be expected) there was a *general* agreement in the direction of the corresponding parts of the two surveys, there was yet a distinct minute difference, and such was the divergence of positions as the laying down of the two series of lines progressed, that the final positions were 120 links apart; and this difference, taking into account the length of a straight line drawn from the initial to the final positions in the two surveys, showed that the magnetic bearing of the first line of the angular survey, used as a base line for reduction, was 59′ in error when compared with the *average* of the readings of the lines of the magnetic survey: further particulars of this case are given at pages 212, 213, &c.

Satisfied that the variations which we had here so carefully observed were not the result of what are generally called accidental or removable causes, peculiar to this particular colliery, we have from time to time, over a number of years, and with different instruments, and under a variety of circumstances, both on the surface and in the underground workings, taken steps to observe the peculiarities of the action of the magnetic needle; and we have, as a consequence, found that a variation more or less is very general—more general, indeed, than is a continuous accurate parallelism.

We will now give some examples in detail to show this variation of the needle more forcibly. Example A.—In a heading crossing the pitch of the strata from one vein of coal to another (technically called "crossing the measures"), a straight line was carefully ranged out, and at nearly equal distances apart, over a total length of about 60 yards, the instrument was set up five times in correct alignment, and the magnetic bearing of the lights previously fixed at the two ends of the line were observed and recorded for each position; and the result was that what is generally supposed would have been, within narrow limits, five similar readings, turned out to be the following series:—174° 3′, 175° 21′, 174° 45′, 172° 30′, and

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174° 40′, thus indicating a maximum variation equal to 2° 51′.

Example B.—In a heading driven in a vein of coal 4 feet thick, and into and through a piece of faulty ground, consisting mainly of a mixture of rock and cliff, a line of about 60 yards in length was arranged out as before, and the instrument was first fixed at that end of the line away from the "fault," and the light then observed at the other end of the line within the faulty ground, and the magnetic bearing read and entered. Seven other positions were then fixed upon in correct alignment in succession towards the other end, and the readings taken at each, and the result was the following series of magnetic bearings, viz.:—36° 24′, 36° 20′, 37° 50′, 38° 15′, 39° 40′, 39° 10′, 38° 10′, and 37° 0′, indicating in this case a maximum variation equal to 3° 20′.

In this example the line of the fault crossing the alignment of the several positions was an acute angle,—at the first position the fault being on the left hand, and from thence forward it gained upon the surveyed line, so that the sixth position was nearly in the line of intersection of the two, and the seventh and eighth positions were within the fault. By referring to the several readings above, it will be observed that there was an increasing divergence in the same direction in approaching to the fault line, and that after entering the fault there was a sudden twist back again in the opposite direction.

Example C.—A series of magnetic bearings was taken in an engine plane underground, which had been driven quite straight from end to end, and over a length of about 330 yards the following readings were accurately observed, viz.:—346° 55′, 345° 0′, 346° 42′, 346° 15′, 345° 0′, 346° 37′, 346° 9′, 345° 48′, and 347° 3′, thus showing, in this example, a maximum difference equal to 2° 3′.

Repeated trials on carefully ranged-out surface lines do not indicate so great a variation of magnetic readings as underground lines, but even these show frequently a marked variation.

The following examples are given as evidence of this:—

Example D.—On a surface line of about 30 chains in length,

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the instrument was set up five times in correct alignment, and observations taken, and in this particular example the reading at each position corresponded precisely with all the others.

From one end of the preceding line, and almost at right angles with it, another line of about 24 chains was ranged out in the same manner as before, and the following series of magnetic readings was the result of Example E:—54° 58′, 54° 51′, 54° 44′, and 54° 58′; this series, therefore, indicates but a very slight variation.

Example F.—In a long carefully ranged base line of a surface survey several observations were taken as at other times, and the following were amongst the readings, viz.:—114° 41′, 114° 41′, 115° 7′, 115° 21′, showing in these a maximum variation of 40′. This variation, although it does not look so formidable as some of those in the previous examples, yet when analyzed it represents something too serious to be disregarded; for when viewed in reference to the length of that section of the line at the extremities of which the instrument was set up and the readings taken—in one case 40 chains, and in another 26·45 chains—we find that in the former case the twist of position due to the variation experienced is equal to 46·5 links, and in the other case it is equal to 30·7 links; and these are twistings of the true position of a station in a surface survey which cannot safely be overlooked.

We have also made the experiment of setting the instrument on a fixed station, and of observing a distant object, taking the instrument several times to the same position at intervals of some months apart, and we have not always found a close agreement in the magnetic bearing of the same object.

The foregoing examples, confirmed by many other observations made from time to time, plainly indicate that the magnetic needle does not, even when used on the earth's surface, maintain generally an accurate parallelism; and that when used in underground surveying operations the variations are, as a rule, much more considerable.

What the intrinsic change really is which a piece of steel undergoes in the process of being magnetised and converted into a magnetic needle we have never been able to understand

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to our own satisfaction; but our observations lead us to suppose that whatever the *internal* change may be upon the steel, it results *externally* in imparting to the needle the power to *conform to the direction* of the current of electricity, or magnetism, passing around it at the moment, and in the position in which it is being used.

We have observed on different occasions that the needle seems to be more deflected from its true parallelism when used in close proximity to faulty and disturbed ground, and also when used in headings passing through such varying ground as is met with in what is technically known as "crossing the measures," than in strata of a more uniform nature, whether it be an ironstone mine or a coal mine; and the conclusion we arrive at, in view of these experiences and circumstances, is that the needle deflections represent the deflections of the passing current of electricity, or magnetism, in the surrounding strata, and that these deflections of the current are again in their turn the result of the varying powers of conduction possessed by the varying strata of the earth—that, in fact, as water partly turns aside from the more confined parts of its channel to find the freest exit and most uninterrupted flow in the more capacious of its numerous passages, so does the electric current get a little deflected, first on one side and then on the other, in its flow through the strata of the earth, the best conductor conveying the greater quantity; and when this superior conductor comes to an abrupt end, or becomes distorted or disturbed, either from the presence of a "fault" or some other disturbing cause, the current becomes more or less deflected, and the magnetic needle, if used in proximity to such a disturbing cause, would also in its turn become deflected in sympathy with the current. This, at least, is the conclusion we have been led to draw in reflecting upon these magnetic-needle disturbances, and the probable cause of them.

As has been previously remarked, the needle should be carefully set to zero, or 360°, and the bearings of the successive lines read off both the verniers, and a check upon their accuracy exercised by observing if the greater reading is = the lesser + 180°. Having numbered the line on the book and

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entered the bearings of it, proceed with the chaining as described in the chapter on "Traversing," in the "Mineral Surveyor's Guide." Then in plotting a "periodical" survey add a quantity to each bearing at the rate of $7\frac{1}{2}'$ per annum for the whole period, from the time or year represented by the magnetic meridian line on the plan to the time of taking the survey, and the new bearings will be a very near approximation to the magnetic meridian for the time being.

When a surveyor first takes to the responsible care of plans and surveys of this nature, and there is any reason to doubt the accuracy of the magnetic meridional line upon the plan, or if its present divergence is uncertain, it should be carefully checked so soon as practicable, so that a judgment may be formed how to deal with the plotting of new surveys. This need not be a difficult operation, and its performance will afford an insight into the condition of the plan, and be a reliable datum for future working. To prove the meridian line of a plan the best way, probably, will be to take two, or perhaps three, salient angles in the boundary of the property, and which should extend over some 30 or 40 chains, if the size of the property admits of it (but for a smaller property a shorter aggregate length will suffice), and between these angles of the boundary, and embracing each of them particularly, take a series of magnetic lines, without seeking to have them individually very long; and then, after having plotted them on a separate piece of paper, with the salient angles of the boundary properly delineated, transfer a copy of the same on to the general plan, and compare the new meridian line from which it was plotted with that on the plan formerly laid down, in their relation to the portion of the boundary now taken, and it will then be immediately seen how they stand in relation to each other, and what has been the variation of the meridian since the original line was first laid down upon the general plan.

A copy of the record of the mean annual variation of the magnetic meridian at Greenwich Observatory, over any series of years specified, may be readily obtained through the courtesy of the Astronomer Royal, and this will supply the data on

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which to make the correction in plotting the survey; and the notes of the survey should bear a distinct indication of the quantity added to the readings of that particular survey, and of the date on which it was made.

CHAPTER III.

ANGULAR SURVEYING.

We will now indicate how an angular survey should be conducted, premising that, as regards chaining of lines, the necessity for care is the same in both systems.

Suppose there is, say, an engine plane, into the present end of which it is required to drive from another district of the mine in the same stratum of ground, so that the new drivage shall be in correct alignment with the part already in operation, and when completed constitute an extension of the same engine plane.

The centre line of this engine plane should in this case be made the zero line of the angular survey, and the series of angles taken in working the survey round from the present end of the plane to the place where the new drivage is to be commenced is to be "reduced" into this zero line (see examples), and from these "reduced readings" there may be determined the aggregate divergence at any particular position or line in the survey, as well as the divergence of the terminal position of the survey, and the point to be given to the new part.

After having made two marks in the roof or floor (the former is preferable), for subsequent reference if required, lined out in exact accordance with the centre of the plane, and at from 40 to 50 yards apart, if practicable, set up the instrument to be used in making the survey so that it shall agree vertically with the alignment marks in the centre line of the plane, and at that mark which lies in the direction of the succeeding line (which will be No. 2), and by observing a light placed at the

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other mark, take this line as zero, and send a light forward in the direction in which the survey is to be made, and have it conveniently placed so that the instrument can presently be fixed vertically over it. The instrument will now stand between two fixed lights placed as "sights," and these and the instrument will constitute the first two lines of the survey, and the first observations to be taken at every position the instrument is fixed in are called "back sights." In reading the instrument for angular surveying, it is necessary to bear in mind that *one* vernier only should be read, and that this should *invariably* be that vernier that lies on that side of the compass-box *in the direction in which the survey is progressing*, or that which is next the surveyor when he stands at the instrument to take the *back sight*, or the light at the starting point. In this way, then, take the first back sight and cramp the base of the dial, and read the vernier and enter the reading in the column of "back readings;" then stand on the opposite side of the instrument and turn the limb round so as to observe the forward light set as before indicated, and again read the *same* vernier as before, and place the reading in the column of "forward readings." Next uncramp the base of the dial and turn it bodily round a little, and then take another observation of the back light as before, and again cramp the dial, and after observing the reading put it as before in the column of "back readings," immediately above the previous entry; after which turn the limb only round again to the fore light, taking and entering it as before immediately above the preceding "forward reading." By proceeding thus, a slight consideration will show that the respective readings will themselves indicate whether the divergence of the second with the first line has been to the *right* or to the *left*, for if to the *right* the back readings will be less than the forward readings (unless the zero of the dial-box has been passed over, which can, in the majority of cases that will occur, be easily avoided), and if to the *left* the back readings will be greater than the forward readings. Bearing this in mind, then, and proceeding invariably in this way, it will not be necessary for the surveyor to make any entry in his book for the express purpose of showing

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which way the successive lines of the survey turn, for the relative magnitude of the backward and forward readings, in their respective columns in the book, will be an infallible indication of this in themselves.

Then cast out respectively the "differences" of these two double observations by taking the less from the greater in each case, and place them one under the other in the next column (see example following), and compare them with each other; if the two results are within from 2′ to 4′ of each other the mean of the two may be taken as the (sufficiently) accurate measure of the diverging angle. Occasionally, through the imperfection of the instrument, it may be found that the difference between the two results will be so much as from 6′ to 8′, and then a third trial should be made, and a mean of the three observations taken as the measure of the angle. If the "forward readings" are greater than the "back readings" the divergence is to the *right*, and the difference is to be *added* to the zero (either 0° or 360°, as may be chosen for it), and if the reverse it is to be subtracted from it, and by placing the marks + or — to the "mean difference," as the case may require, the operation will be plainly indicated. Two observations *at least* should be taken from each position, and the differences worked out before removing the instrument, and then the surveyor may place implicit confidence in the accuracy of his readings and entries. Before removing the instrument from its first position carefully fix a light under it, adjusted in position with a plummet.

As regards chaining the *zero line* of the survey it is to be observed that if the new drivage is to come into that position in the original plane at which the instrument *is first fixed*, the line does not require to be chained (as in example 1); but if the new drivage is to come into the position occupied by *the light* on to which the *first back* reading is taken the line is to be chained, as in example 2; all subsequent lines are of course to be carefully chained, and the order of proceeding is to chain up to the instrument *after* the forward sights have been taken.

The instrument is next to be moved forward *on* to the *forward light* and be set right over it with a plummet, and the

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light which was under it at its first position now becomes the *back* sight to the second position (the first back sight having now been removed), and a new forward sight is conveniently placed in position as before, and the same operation repeated in detail both in taking the angles and in chaining the lines successively throughout the survey. The two ends of the last line taken, or two accurately defined positions in its alignment, should be marked in the roof or floor, from which, and from the record of them in the chaining after the survey has been worked out by the "traverse tables" (or it may be by *plotting*, but by the traverse tables is the most accurate), the position to start the new drivage, and the direction to be given to it, can be determined.

We now present example 1 of this method of working a survey, and in which line 1 is the centre of an engine plane, and the instrument was first fixed in that end of it into which the new extension was to be driven ; consequently the length of line 1 is immaterial for working out the traverse, or for plotting from the "reduced" readings, but the actual length observed in the first back readings should be sufficient to define accurately the alignment of the engine plane centre.

The headings descriptive of the different columns of figures show what they severally represent.

The figures in the column headed "Traversing Angle" are found in the same way as is described at page 20, &c., of "Mineral Surveyor's Guide, treating of the operation of traversing, and the lines of this example were worked out from the traverse tables, and the position for starting the required drivage and the direction to be given to it were defined before coming out of the colliery, and without making any plotted plan of the same; and when the drivage was completed both the position for starting and the "point" for the same were proved to have been quite accurately defined and given from the traverse. The "reduced reading" of line 7 is seen (page 201) to be 75° 58½′; and with *this reading* set on the back sight (being then the position in which lines 6 and 7 meet) when the instrument is placed on the length 182, turn the limb round to 360° or zero, and the sights will then give the alignment of the engine

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EXAMPLE I.—Angular Survey and Traverse Angles Combined.

No. of Line.	Back Readings.	Forward Readings.	Differences.	Mean Differences.	+ or −	Reduced Readings.	Traverse Angle.	Quadrant.	Length of Line.	Remark.
7	157° 30′ 141° 30′	173° 32′ 157° 30′	16° 2′ 16° 0′	16° 1′	+	75° 58½′	75° 58½′	N.E.	182	
6	89° 53′ 22° 17′	157° 49′ 90° 10′	67° 56′ 67° 53′	67° 54½′	+	59° 57½′	59° 57½′	N.E.	249	
5	181° 22′ 159° 15′	203° 26′ 181° 22′	22° 4′ 22° 6′	22° 5′	+	352° 3′	7° 57′	N.W.	116	
4	156° 49′ 154° 30′ 152° 4′	159° 8′ 156° 51′ 154° 30′	2° 19′ 2° 21′ 2° 26′	2° 22′	+	329° 58′	30° 2′	N.W.	224	
3	149° 10′ 146° 12′	152° 6′ 149° 10′	2° 56′ 2° 58′	2° 57′	+	327° 36′	32° 24′	N.W.	286	
2	316° 19′ 360° 0′	280° 58′ 324° 39′	35° 21′ 35° 21′	35° 21′	—	324° 39′	35° 21′	N.W.	192	
1		Zero Line				360° 0′	Zero	Length indefinite.		

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plane exactly in prolongation of line 1. The position in line No. 7 (182) where the alignment of the plane crossed it was known approximately from the general plan of the workings, but its actual and accurate position was discovered from the traverse computation of the survey, which was at that place in it when the totals of the "Eastings" and of the "Westings" were found to be equal, and therefore cancelled each other; and the net "Northing" or "Southing" of the traverse will give the length to be driven, so as to work through to the position where the instrument was first set up. The working out of this traverse will form a useful exercise, as would also the plotting of the same from the "reduced readings." It will be observed that line No. 4 has three complete observations to determine the divergence, and it will be well to explain that the third was taken because on examination there was found to be a difference of 5 minutes between the first and second, and a further check was considered advisable.

EXAMPLE 2.—This is a survey for a somewhat similar purpose as the preceding example, and No. 1 line commences in the end of the engine plane as then worked, and agrees with the centre line of it; and from thence the series of lines of the survey were taken through a winding course of workings to the position to which it was intended to extend the plane, and from which the extension had to be driven, and the engine plane centre was made the zero as before for obtaining the "reduced readings" of the survey, worked out in the manner previously described.

If we now work out this angular survey by the traverse tables, we shall find that the terminus of the line No. 24 is in exact alignment with the direction of the centre line of the plane, and which is found to be the case because in that position the "Eastings" and "Westings" are equal, and consequently they cancel each other; and as the "reduced reading" of No. 24 line is = 335° 48½', what we have further to do in order to give the point to the drivage that is to constitute a true prolongation of the engine plane, is, to fix up the instrument accurately at the position of the length 80 of line No. 24 at which the measurement terminated, and with the vernier

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upon the above angle of the instrument when the sights are pointed back upon the mark left at the other end of the line 24 tighten the body of the instrument and turn the limb round to zero, and the sights will then indicate the correct direction for the new drivage, from which the requisite points for the same may be given; further, by a summation of the "Northings" and "Southings" the exact distance to be driven may be found. We give herewith the particulars of the survey of this example as entered, commencing at the top of the page and working downwards, instead of the reverse, as in the previous example.

We also present a traverse of the survey, worked out from the traverse tables.

The exact position in line 24 which agreed with the alignment of the engine plane (line 1) was not at the time of taking the survey accurately alighted on; but after working out the survey traverse for a shorter length of that line, it was discovered that by extending it to the length indicated in the traverse the summation of the "Eastings" and "Westings" would be 0, and thus the true position was known and acted upon for determining the line of new drivage, and the result of acting upon it was perfectly satisfactory.

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EXAMPLE II.

No. of Line.	Back Readings.	Forward Readings.	Differences.	Sign of Diff.	Mean Difference.	Reduced Reading.	Traverse Angle.	Quadrant.	Length of Line.	Remark.
1	Zero Line.		. .		. .	0° 0′	. .	N.	480	
2	131° 30′ 74° 16′	254° 18′ 197° 8′	122° 48′ 122° 52′	+	122° 50′	122° 50′	57° 10′	S.E.	73	
3	197° 18′ 150° 15′	150° 15′ 103° 14′	47° 3′ 47° 1′	—	47° 2′	75° 48′	75° 48′	N.E.	232	
4	282° 52′ 269° 12′	269° 13′ 255° 34′	13° 39′ 13° 38′	—	13° 38½′	62° 9½′	62° 9½′	N.E.	153	
5	75° 29′ 87° 13′	87° 13′ 98° 53′	11° 44′ 11° 40′	+	11° 42′	73° 51½′	73° 51½′	N.E.	205	
6	216° 29′ 256° 13′ 295° 58′	256° 12′ 295° 58′ 335° 35′	39° 43′ 39° 45′ 39° 37′	+	39° 42′	113° 33½′	66° 26½′	S.E.	41	
7	42° 50′ 65° 5′	65° 5′ 87° 20′	22° 15′ 22° 15′	+	22° 15′	135° 48½′	44° 11½′	S.E.	155	
8	87° 10′ 107° 30′	107° 30′ 127° 50′	20° 20′ 20° 20′	+	20° 20′	156° 8½′	23° 51½′	S.E.	46	
9	57° 25′ 91° 53′	91° 53′ 126° 22′	34° 28′ 34° 29′	+	34° 28½′	190° 37′	10° 37′	S.W.	50	
10	119° 1′ 154° 49′	154° 49′ 190° 37′	35° 48′ 35° 48′	+	35° 48′	226° 25′	46° 25′	S.W.	131	
11	198° 10′ 197° 46′	197° 46′ 197° 18′	0° 24′ 0° 28′	—	0° 26′	225° 59′	45° 59′	S.W.	169	

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12	195° 7′ 194° 48′	194° 48′ 194° 25′	0° 19′ 0° 23′	—	0° 21′	225° 38′	45° 38′	S.W.	80
13	194° 29′ 198° 23′	198° 23′ 202° 20′	3° 54′ 3° 57′	+	3° 55½′	229° 33½′	49° 33½′	S.W.	71
14	22° 43′ 48° 44′	48° 52′ 74° 54′	26° 9′ 26° 10′	+	26° 9½′	255° 43′	75° 43′	S.W.	78
15	254° 34′ 205° 55′	205° 55′ 157° 18′	48° 39′ 48° 37′	—	48° 38′	207° 5′	27° 5′	S.W.	88½
16	158° 16′ 95° 40′	95° 40′ 33° 2′	62° 36′ 62° 38′	—	62° 37′	144° 28′	35° 32′	S.E.	39
17	33° 22′ 65° 44′	65° 44′ 98° 4′	32° 22′ 32° 20′	+	32° 21′	176° 49′	3° 11′	S.E.	59
18	278° 22′ 287° 13′	287° 13′ 296° 2′	8° 51′ 8° 49′	+	8° 50′	185° 39′	5° 39′	S.W.	178
19	116° 1′ 137° 2′	137° 2′ 158° 3′	21° 1′ 21° 1′	+	21° 1′	206° 40′	26° 40′	S.W.	94½
20	157° 38′ 109° 0′	109° 0′ 60° 18′	48° 38′ 48° 42′	—	48° 40′	158° 0′	22° 0′	S.E.	64½
21	60° 54′ 175° 52′	175° 52′ 290° 55′	114° 58′ 115° 3′	+	115° 0½′	273° 0½′	86° 59½′	N.W.	63
22	252° 24′ 250° 26′	250° 26′ 248° 28′	1° 58′ 1° 58′	—	1° 58′	271° 2½′	88° 57½′	N.W.	70
23	248° 27′ 226° 2′	226° 2′ 203° 39′	22° 25′ 22° 23′	—	22° 24′	248° 38½′	68° 38½′	S.W.	165
24	23° 35′ 110° 45′	110° 47′ 197° 53′	87° 12′ 87° 8′	+	87° 10′	335° 48½′	24° 11½′	N.W.	80

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TRAVERSE OF EXAMPLE II.

No. of Line.	Angles of Traverse.	Sign of Quad.	Length.	Latitude.		Departure.	
				North.	South.	East.	West.
1	0′	..	480	480·00	..	..	..
2	57° 10′	S.E.	73	..	39·57	61·33	..
3	75° 48′	N.E.	232	60·83	..	223·88	..
4	62° 9½′	N.E.	153	71·45	..	135·28	..
5	73° 51½′	N.E.	205	56·99	..	196·92	..
6	66° 26½′	S.E.	41	..	16·38	37·58	..
7	44° 11½′	S.E.	155	..	111·13	108·03	..
8	23° 51½′	S.E.	46	..	42·07	18·60	..
9	10° 37′	S.W.	50	..	49·14	..	9·20
10	46° 25′	S.W.	131	..	90·30	..	94·88
11	45° 59′	S.W.	169	..	117·41	..	121·54
12	45° 38′	S.W.	80	..	55·94	..	57·19
13	49° 33½′	S.W.	71	..	46·05	..	54·03
14	75° 43′	S.W.	78	..	19·25	..	75·58
15	27° 5′	S.W.	88½	..	78·77	..	40·29
16	35° 32′	S.E.	39	..	31·73	22·67	..
17	3° 11′	S.E.	59	..	58·90	3·27	..
18	5° 39′	S.W.	178	..	177·13	..	17·52
19	26° 40′	S.W.	94½	..	88·44	..	42·39
20	22° 0′	S.E.	64½	..	59·80	24·17	..
21	86° 59½′	N.W.	63	3·30	..	..	62·91
22	88° 57½′	N.W.	70	1·27	..	..	69·99
23	68° 38½′	S.W.	165	..	60·07	..	153·67
24	24° 11½′	N.W.	80	72·96	..	..	32·78
				746·80	1142·08	831·73	831·98
					746·80		
		Net Southing	..		395·28		

EXAMPLE 2.—In this example we have an angular survey for a somewhat different purpose, and it is taken from the top and centre of an underground shaft, which had been sunk to another vein of coal lying beneath, and in which it was intended to drive a return air-way into the bottom of the same shaft, for purposes of ventilation. An arbitrary "reduced reading" is given to No. 1 line, and the succeeding lines are reduced into it, and from the series are obtained the successive

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traverse angles. The survey terminated with line No. 15, and the direction of No. 16 line was the thing to be determined by the survey, and its length.

After working out the traverse as in the example, the summation of the results is found to be a "Northing" = 137·06 links, and a "Westing" = 159·69 links; by treating these resultants in the same way as is described at pages 32 and 33, chap. 7, of the "Mineral Surveyor's Guide," we find that the required angle is 48° 39′, and the length to be driven into the centre of the air-pit 207·4 links.

To see the use that is to be made of this angle, 48° 39′, it must be understood that it is assumed that there were marks carefully set up and left at each end of the line No. 15, so that the instrument can be fixed accurately at the innermost of them; and having set up the instrument in this position, and with the vernier set at the reduced reading for that line—viz. 50° 50½′—and the sights turned back on the mark at the commencement of the line, tighten the compass box in that position, and then turn the limb to read 48° 39′, and this will be the required direction to be given to the drivage, and the distance to the centre of the pit is indicated by line 16 = 207·4.

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EXAMPLE III.

No. of Line.	Back Readings.	Forward Readings.	Differences.	Mean Difference.	Sign of Diff.	Reduced Reading.	Traverse Angle.	Quadrant.	Length of Line.	Remark.
1	Zero Line.					77° 16′	77° 16′	N.E.	27	
2	32° 4′ 206° 55′	120° 14′ 295° 2′	88° 10′ 88° 7′	88° 8½′	+	165° 24½′	14° 35½′	S.E.	322	
3	119° 13′ 118° 10′	118° 9′ 117° 2′	1° 4′ 1° 8′	1° 6′	—	164° 18½′	15° 41½′	S.E.	266	
4	299° 54′ 302° 51′	302° 51′ 305° 49′	2° 57′ 2° 58′	2° 57½′	+	167° 16′	12° 44′	S.E.	309	
5	141° 11′ 161° 9′	161° 9′ 181° 0′	19° 58′ 19° 51′	19° 54′	+	187° 10′	7° 10′	S.W.	62	
6	181° 2′ 219° 40′	219° 40′ 258° 12′	38° 38′ 38° 32′	38° 35′	+	225° 45′	45° 45′	S.W.	61	
7	78° 5′ 96° 43′	96° 43′ 115° 19′	18° 38′ 18° 36′	18° 37′	+	244° 22′	64° 22′	S.W.	153	
8	115° 34′ 197° 48′	197° 48′ 280° 6′	82° 14′ 82° 18′	82° 16′	+	326° 38′	33° 22′	N.W.	247	

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9	195° 15′ 112° 16′	112° 35′ 119° 32′	7° 20′ 7° 16′	7° 18′	+	333° 56′	26° 4′	N.W.	104	
10	155° 7′ 180° 29′	180° 35′ 206° 0′	25° 28′ 25° 31′	25° 29½′	+	359° 25′	0° 35′	N.W.	163	
11	20° 16′ 10° 24′	10° 23′ 0° 35′	9° 53′ 9° 49′	9° 51′	−	349° 34½′	10° 25½′	N.W.	166	
12	163° 2′ 163° 42′	163° 39′ 162° 19′	1° 23′ 1° 23′	1° 23′	−	348° 11½′	11° 48½′	N.W.	90	
13	153° 30′ 167° 55′	167° 55′ 182° 20′	14° 25′ 14° 25′	14° 25′	+	2° 36½′	2° 36½	N.E.	135	
14	52° 46′ 41° 10′	41° 14′ 29° 32′	11° 32′ 11° 38′	11° 35′	−	351° 1½′	8° 58½	N.W.	34	
15	24° 36′ 84° 25′	84° 25′ 144° 14′	59° 49′ 59° 49′	59° 49′	+	50° 50½′	50° 50½	E.	22	

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TRAVERSE OF EXAMPLE III.

No. of Line.	Angle of Traverse.	Quad. of Traverse.	Dist. in Links.	Latitude.		Departure.	
				North.	South.	East.	West.
1	77° 16′	N.E.	27	5·95	..	26·34	..
2	14° 35½′	S.E.	322	..	311·59	81·16	..
3	15° 41½′	S.E.	266	..	256·08	71·92	..
4	12° 44′	S.E.	309	..	301·39	68·08	..
5	7° 10′	S.W.	62	..	61·51	..	7·74
6	45° 45′	S.W.	61	..	42·57	..	43·70
7	64° 22′	S.W.	153	..	66·19	..	137·92
8	33° 22′	N.W.	247	206·28	..	..	135·84
9	26° 4′	N.W.	104	93·42	..	..	45·69
10	0° 35′	N.W.	163	162·98	..	..	1·67
11	10° 25½′	N.W.	166	163·25	..	..	30·13
12	11° 48½′	N.W.	90	88·09	..	..	18·42
13	2° 36½′	N.E.	135	134·84	..	6·16	..
14	8° 58½′	N.W.	34	33·58	..	..	5·30
15	50° 50½′	N.E.	22	13·88	..	17·06	..
		Totals .		902·27	1039·33	270·72	426·41
					902·27		270·72
		Summation . .			137·06	and	155·69
16	48° 39′	N.E.	207·4	137·03		155·69	
		Final Totals		1039·30	1039·33	426·41	426·41

These three foregoing examples, then, will indicate one or two classes of work in surveying that will be best executed by making use of this method of working instead of employing the magnetic needle. It is not intended to deny that excellent results have been and often are obtained with the use of the needle even in the class of work referred to in these examples. A good instrument in the hands of a good surveyor is often so employed, but the same amount of confidence in the accuracy of an important work laid out from a needle survey cannot be felt as in the other properly made; and in such matters as engine planes, &c., it is of first importance to insure thorough accuracy of alignment, and this, there can be no question, can be more confidently assured by angular work.

But there are other occasions in operations of great im-

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portance requiring accurate surveying when both systems may be usefully employed, one as supplementary to the other. As we have before said, under conditions suitable to its employment, the angular system, properly carried out, will give the delineation of a series of lines taken in the mines with more absolute truth than the magnetic system; and when there is no question of adjusting those workings to surface positions, or of defining their relative position to some other workings in some other mine either higher or lower in the strata, their duplication by magnetic lines will be of no advantage.

But now take the case where two veins of mineral are raised from the same pair of shafts, and one of which veins is much deeper than the other. Probably at some point far removed from the shaft it is desired to sink from one vein to the other for ventilating or other purposes, and to insure that this may be properly entered upon an independent survey in both veins may be required to be made in order to show their accurate relative position. It is most likely that in the vicinity of the shaft, in both veins, there are many things that render the employment of the magnetic needle in those particular places unadvisable and attended with too much uncertainty. And if the angular system be solely employed, we have to consider that a shaft intervenes between the workings of these two veins of mineral; and this involves the employment of some plan of hanging lines in the shaft in order to effect a connection between the two series of lines. This is, however, by no means free from risks, and cannot always be safely done, filled as these shafts generally are with the ordinary appurtenances of a working shaft raising mineral. Under circumstances such as these, the method that will be likely to insure the greatest accuracy is to first make a careful angular survey, in both veins, of the entire workings required to be embraced by the operations on the plan previously described, and having the centre of some known vertical line in the shaft as a base common to both, and plot them as two separate series; each of these will be complete in itself so far as regards the delineation of the particular workings in which they are taken, but lacking the magnetic meridian or any common datum by which the two

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series of lines may be accurately placed and brought into true relative position each to the other. To enable this to be done, the better plan will be to take as much of each section of the former sets of lines over again with the needle—making, in fact, a careful needle survey of the same route in each over some considerable length, where it can be safely done, and without aiming to *have over-long lines;* and having plotted them separately, determine the magnetic meridian of each of the former angular series by laying down a corresponding copy of the latter on the top of each of them respectively, taking care to insure accurately corresponding positions in the two surveys in each vein. Thus the magnetic meridian may be laid on to the delineation of the angular survey from that of the magnetic in each case, and finally the two angular series brought together on the base of the common magnetic line.

If this be carefully carried out it will insure a greater degree of accuracy than any other system for this particular class of operation; and it will be equally applicable whether it be to two series of workings from the same shaft at different levels, or whether they be from shafts widely separated *from each other*, and surface lines intervene. It is really more difficult to insure accuracy in distances by chaining, if there is much irregularity in the dip of the strata, than in the instrumentation of a survey.

In taking an angular survey it will not be sufficient, in order to be able to fix the magnetic meridian to the plotted lines, to take the magnetic bearing of the first or any intermediate line, and assume that the meridian is thus determined for the whole if the several angles are "reduced" into this magnetic angle as a base. It may just happen that the magnetic meridian of the series can or fortuitously may be determined in this way in some one instance by chance, but it is far too uncertain of attainment to assume that it will be so in any particular case; and if it should be found to result so in some one case, it will most probably be far otherwise in nineteen others.

We now present the particulars of a case previously mentioned (page 192) in which this plan of duplication was followed out; and it is an interesting example of the comparative (but

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not exact) accordance of two series of lines over the same course of workings, one taken with the magnetic needle and the other without the needle, and with the lengths of the lines intentionally varied in the two. We give the particulars of the two surveys, so that they may be readily laid down on paper by any one desirous of following the matter out so as to see their degree of accordance. The series A are the "magnetic" bearings and lengths of the lines taken, and the series B are the "angular" bearings and the lengths of the lines so taken; the magnetic bearing of the first line only in the latter series being very carefully taken so as to get a base to work upon in taking the angles of the subsequent lines, and for working out the "reduced readings," and at each subsequent position of the instrument the clamped sights were carefully set back on the preceding position it had occupied, and the limb then released and turned round on to the forward sight. The result of these two series, when plotted from the same point of departure on the paper, and with the same meridian line, was, as we have said (see p. 192), to show a divergence between the two of 120 links at the final positions attained at the end of both, and if the series B be plotted *with* 59′ *added to each reading*, the final position will be found to accord with the final position of the series A, and at the intermediate points to be in *approximate* accordance with it. The development of the series B on the plan will really define the accurate delineation of the underground workings, and in so far as there is a divergence between the two series at any intermediate position the error will lie on the side of series A, or magnetic readings.

SERIES A.—MAGNETIC SURVEY.

410.	519
252° 45′ op. 72° 45′.	254° 50′ op. 74° 50′.
(2).	(4).
342.	504.
253° 45′ op. 73° 45′.	253° 50′ op. 73° 50′.
(1).	(3).

First line of the Survey.

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288.
290° 18′ op. 110° 18′.
(15).

307.
302° 3′ op. 122° 3′.
(14).

256.
318° 27′ op. 138° 27.
(13).

140.
327° 39′ op. 147° 39′.
(12).

301.
321° 57′ op. 141° 57′.
(11).

119.
305° 15′ op. 125° 15′.
(10).

628.
297° 18′ op. 117° 18′.
(9).

412.
295° 24′ op. 115° 24′.
(8).

581.
294° 39′ op. 114° 39′.
(7).

730.
294° 39′ op. 114° 39′.
(6).

58.
283° 45′ op. 103° 45′.
(5).

End of the Survey.

103.
282° 15′ op. 102° 15′.
(25).

258.
304° 24′ op. 124° 24′.
(24).

206.
309° 54′ op. 129° 54′.
(23).

84.
295° 51′ op. 115° 51′.
(22).

91.
263° 36′ op. 83° 36′.
(21).

132.
242° 9′ op. 62° 9′.
(20).

188.
242° 51′ op. 62° 51′.
(19).

334.
273° 6′ op. 93° 6′.
(18).

153.
291° 0′ op. 111° 0′.
(17).

566.
299° 57′ op. 119° 57.
(16).

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Series B.—Angular Survey.

171.
293° 48′ op. 113° 48′.
(10).

313.
293° 21′ op. 113° 21′.
(9).

552.
294° 30′ op. 114° 30′.
(8).

588.
294° 9′ op. 114° 9′.
(7).

738.
293° 48′ op. 113° 48′.
(6).

50.
280° 51′ op. 100° 51′.
(5).

633.
253° 15′ op. 73° 15′.
(4).

435.
251° 42′ op. 71° 42′.
(3).

255.
254° 18′ op. 74° 18′.
(2).

450.
253° op. 73°.
(1).

First line of the Survey.

166.
292° 48′ op. 112° 48′.
(20).

245.
300° 51′ op. 120° 51′.
(19).

317.
299° 3′ op. 119° 3′.
(18).

179.
286° op. 106°.
(17).

167.
296° 42′ op. 116° 42′.
(16).

240.
304° 27′ op. 124° 27′.
(15).

247.
319° 26′ op. 139° 26′.
(14).

128.
327° op. 147.
(13).

305.
320° 6′ op. 140° 6′.
(12).

111.
301° 45′ op. 121° 45′
(11).

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89.
259° 30 op. 79° 30.
(25).

287.
242° 27′ op. 62° 27′.
(24).

54.
260° 36′ op. 80° 36′.
(23.)

124.
273° 27′ op. 93° 27′.
(22).

198.
274° op. 94°.
(21).

End of the Survey.

101.
278° op. 98°.
(29).

306.
303° op. 123°.
(28).

165.
307° 39′ op. 127° 39.
(27).

89.
290° 48′ op. 110° 48′.
(26).

(N.B.—These series, A and B, start from the same position.)

The foregoing, then, presents a fair illustration of how near an approximation to the truth the result of a magnetic survey may be found to come where there are no special circumstances which render the system inapplicable in any section of its length, such as those we have indicated above. Such a case was that which we shall next present, in which there were so many disturbing elements in a part of the district in which the working lay that the needle could not have been used with any approach to safety, but another part of it presented no objectionable features. It was desired to connect distant and totally separated underground workings, having their outlets through separate shafts at a very considerable distance apart. This involved, therefore, the accurate adjustment to each other of surface and underground lines, and the method adopted proved completely satisfactory. The following series C of lines were taken on the angular system over the whole length of the principal "artery" of the underground district of one of the shafts it was desired to connect, and which would give accurately the delineation of the same for the required plan to be based upon; and then from the same

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starting point the series of magnetic lines D were taken over so much of the same route as could safely be done without getting within the reach of more than ordinary disturbing causes; and with this series D carefully plotted and laid and adjusted upon the lines of series C, the magnetic bearing of the latter was so accurately fixed that, with the same principle applied to the other shaft, the "points" for driving through the connection taken from the data so obtained answered perfectly. Examples such as these, therefore, demonstrate the soundness of this principle in operations to which it is applicable.

There is another feature in this case worth remarking upon, and it is this—the almost identity of these two series of lines, so far as D goes, if plotted from the same position on the paper, and taking the zero of the reduced readings of the angular survey to correspond with the magnetic meridian, which in this case it has been made to do. A plot, therefore, of these will show that for a distance of very nearly 40 chains embraced in 12 lines the magnetic bearings were obtained with a very close approximation to the accuracy of "angular" work, and it is a further proof that the magnetic needle is not so unreliable in surveying operations as some would represent it to be.

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Series C.—Angular Survey.

No. of Line.	Back Readings.	Forward Readings.	Differences.	Mean Difference.	Sign of Diff.	Reduced Reading.	Length of Line.	Remark.
20	222° 20′ 293° 0′	151° 30′ 222° 10′	70° 50′ 70° 50′	70° 50′	—	311° 40′	55	
19	106° 37′ 206° 8′	115° 0′ 160° 30′	45° 37′ 45° 38′	45° 37½′	—	22° 30′	65	
18	45° 21′ 65° 21′	25° 23′ 45° 21′	19° 58′ 20° 0′	19° 59′	—	68° 7½′	99	
17	50° 15′ 35° 8′	65° 19′ 50° 15′	15° 4′ 15° 7′	15° 5½′	+	88° 6½′	124	
16	81° 28′ 65° 53′	96° 54′ 81° 23′	15° 26′ 15° 30′	15° 28′	+	73° 1′	60	
15	65° 27′ 64° 57′	65° 55′ 65° 27′	0° 28′ 0° 30′	0° 29′	+	57° 33′	161	
14	65° 17′ 65° 47′	64° 49′ 65° 17′	0° 28′ 0° 30′	0° 29′	—	57° 4′	179	
13	32° 19′ 32° 35′	32° 5′ 32° 19′	0° 14′ 0° 16′	0° 15′	—	57° 33′	218	
12	33° 2′ 33° 35′	32° 27′ 33° 2′	0° 35′ 0° 33′	0° 34′	—	57° 48′	259	

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11	32° 0′ 30° 26′	33° 35′ 32° 0′	1° 35′ 1° 34′	1° 34½′	+	58° 22′	343
10	69° 30′ 71° 44′	67° 12′ 69° 30′	2° 18′ 2° 14′	2° 16′	—	56° 47½′	407
9	50° 18′ 51° 47′	48° 49′ 50° 17′	1° 29′ 1° 30′	1° 29½′	—	59° 3½′	287
8	54° 11′ 55° 30′	52° 50′ 54° 10′	1° 21′ 1° 20′	1° 20½′	—	60° 33′	319
7	54° 40′ 53° 58′	55° 20′ 54° 40′	0° 40′ 0° 42′	0° 41′	+	61° 53½′	821
6	54° 56′ 54° 17′	55° 33′ 54° 56′	0° 37′ 0° 39′	0° 38′	+	61° 12½′	338
5	277° 14′ 278° 9′	276° 15′ 277° 14′	0° 59′ 0° 55′	0° 57′	—	60° 34½′	128
4	277° 54′ 277° 42′	278° 4′ 277° 54′	0° 10′ 0° 12′	0° 11′	+	61° 31½′	329
3	294° 26 295° 23′	293° 28′ 294° 26′	0° 58′ 0° 57′	0° 57½′	—	61° 20½′	401
2	326° 31′ 10° 0′	318° 46′ 2° 21′	7° 45′ 7° 39′	7° 42′	—	62° 18′	403
1						70° 0′	518

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SERIES D.—MAGNETIC SURVEY.

	Magnetic lines terminate.
444. 61° 15′ op. 241° 15′. (6).	360. 56° 30′ op. 236° 30′. (12).
170. 62° 16′ op. 242° 16′. (5).	316. 58° 50′ op. 238° 50′. (11).
235. 61° 25′ op. 241° 25′. (4).	780. 61° 58′ op. 241° 58′. (10).
168. 63° 3′ op. 243° 3′. (3).	247. 62° 0′ op. 242° 0′. (9).
327. 69° 0′ op. 249° 0′. (2).	317. 60° 58′ op. 240° 58. (8).
234. 69° 5′ op. 249° 5′. (1).	266. 60° 53′ op. 240° 53′. (7).

Commencing in the same position as Series C.

We present only one more example in illustration of this branch of the subject, and it does not differ very greatly from the preceding in anything but in the degree of "wandering" which the magnetic influence seems to cause in the action of the needle in the magnetic series F. The series E are a set of lines ("reduced" to a purely arbitrary base) very carefully taken for a special purpose, and it was of importance to procure data from which to fix a meridian to them, so as to be able to subsequently utilise them in connection with a plan of a large district of underground workings, of which they formed a main outlet. The angular series were taken with great care, and the system of repeating each observation before removing the instrument, for the purpose of checking each reading, may be

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taken as giving data for a thoroughly correct delineation of the course of working.

The series D given above, showed a somewhat remarkable agreement, so far as the lines went, with the series C; but if series F be compared in the same way with series E, a striking difference in the two, over two-thirds of the whole length of the series, will be thus shown to have arisen; and from a study of a diagram of the two lines laid one upon the other the conviction seems inevitable that the magnetic influence which determines the direction of the needle in any position in which it is free to move is a flowing, dominating energy, not moving in straight lines over long distances, but describing curves which in detail are sometimes very largely irregular within a comparatively small area, but when considered in regard to points more removed from each other are definite positions in those great curves on the earth's surface which constitute the "curves of equal declination" of the magnetic meridian of the places they refer to.

We do not think it would be of any additional advantage to present a diagram of any of these series of lines in illustration of this subject, because if they were not drawn to a tolerably large scale they could be of no practical utility, and if they were so drawn they would be so large as to be very cumbersome and inconvenient. The figures and particulars of the several series would, in the hands of those desirous of investigating the matter to which they refer, be easily available for plotting to any scale that may be deemed desirable, and can be more profitably studied in that way than by presenting diagrams of them to a small scale. But the practical deduction to be drawn from a review of the results which the magnetic phenomenon presents, when investigated and studied in this way, is, that no reliance can be placed on isolated observations for determining the magnetic meridian for a series of lines or for a plan, but that a systematic development of a considerable number of lines affords the surest data for procuring this result. And in each of the instances indicated in the foregoing examples—series A to F—this principle was proved to be thoroughly reliable by the results that were obtained in acting upon the data procured in each of the cases herein given.

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SERIES E.—ANGULAR SURVEY.

No. of Line.	Back Readings.	Forward Readings.	Differences.	Mean Difference.	Sign of Diff.	Reduced Reading.	Length of Line.	Remark.
15	116° 24′ 113° 28′	118° 54′ 116° 2′	2° 30 2° 34′	2° 32′	+	136° 3′	306	
14	112° 50′ 114° 38′	111° 8′ 112° 56′	1° 42′ 1° 42′	1° 42′	—	133° 31′	260	
13	113° 27′ 112° 37′	114° 15′ 113° 27′	0° 48′ 0° 50′	0° 49′	+	135° 23′	201	
12	113° 5′ 113° 45′	112° 21′ 113° 5′	0° 44′ 0° 40′	0° 42′	—	134° 24′	162	
11	112° 24′ 112° 13′	112° 36′ 112° 24′	0° 12′ 0° 11′	0° 11½′	+	135° 6′	373	
10	111° 5′ 110° 32′	111° 37′ 111° 5′	0° 32′ 0° 33′	0° 32½′	+	134° 54½′	353	
9	46° 23′ 47° 43′	45° 3′ 46° 23′	1° 20′ 1° 20′	1° 20′	—	134° 22′	424	
8	60° 15′ 45° 30′	60° 15′ 45° 30′	0° 0′ 0° 0′	0° 0′	..	135° 42′	425	

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7	30° 5′ 30° 15′	29° 55′ 30° 5′	0° 10′ 0° 10′	0° 10′	—	135° 42′	398
6	25° 33′ 23° 40′	27° 22′ 25° 32′	1° 49′ 1° 52′	1° 50½′	+	135° 52′	470
5	21° 51′ 21° 37′	22° 3′ 21° 51′	0° 12′ 0° 14′	0° 13′	+	134° 11½′	557
4	204° 23′ 205° 46′	202° 59′ 204° 24′	1° 24′ 1° 22′	1° 23′	—	133° 48½′	370
3	221° 19′ 236° 34′	206° 7′ 221° 19′	15° 12′ 15° 15′	15° 13½′	—	135° 11½′	57
2	240° 27′ 180° 2′	300° 52′ 240° 27′	60° 25′ 60° 25′	60° 25′	+	150° 25′	121
1	Zero line ..	..	..	..	..	90° 0′	36

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Series F.—Magnetic Survey.

288.
160° 39′ op. 340° 39′.
(9).

213.
159° 16′ op. 339° 16′.
(8).

533.
163° 42′ op. 343° 42′.
(7).

276.
165° 45′ op. 345° 45.
(6).

313.
166° 35′ op. 346° 35.
(5).

296.
171° 51′ op. 351° 51′.
(4).

329.
169° 25′ op. 349° 25′.
(3).

270.
158° 57′ op. 338° 57′.
(2).

290.
159° 54′ op. 339° 54′.
(1).

This corresponds with 306 of line 15 in Series E. } 349.
163° 56′ op. 343° 56′.
(16).

251.
162° 30′ op. 342° 30′.
(15).

82.
164° 12′ op. 344° 12
(14).

155.
165° 57′ op. 345° 57′.
(13).

241.
164° 33′ op. 344° 33.
(12).

184.
165° op. 345°.
(11).

227.
163° 44′ op. 343° 44′.
(10).

N.B.—This survey commences on 57 of line 3 in the Series E.

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CHAPTER IV

NOTES ON COLLIERY PROPERTY.

THERE can be no question of the fact that the coal mines of Great Britain are a source of great national wealth to the community at large. Very little indeed, comparatively, in the way of manufactures, can be carried on without coal, and the ability to produce and to procure this fuel at a reasonable cost, and of a suitable quality, greatly facilitates the general manufacturing power of the country—is indeed of vital importance to it. But this may be wealth to the community generally, and may be abundantly realised, where yet the immediate proprietors of colliery property are not benefited, or, if benefited at all, yet not adequately so.

When a large sum of money has been expended in sinking pits or in opening outlets for the production of coal, it is so far well for the proprietors if the veins or beds are met with in quality equal to expectation. Very often indeed such is not the case, and under any circumstances there is in the onset an amount of risk about it that deserves to be met by a most adequate return.

Once a colliery is fairly in working order, and in a position to produce a large output, it is to the interest of the proprietor that this should be secured with the least delay; and if the market is only tolerably favourable, a remunerative business may be soon entered upon, while yet the "lead" is short, and circumstances favourable for remunerative production; but if the market rates are adverse to a profitable selling price, the effort to produce largely—if made generally by owners of colliery property—will be likely to throw such a quantity of coal upon the market as will necessarily have the tendency to further depress prices.

The improvement in the cheapening of production in the staple trades of the country, and the efforts generally being

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made with that object in view, will doubtless cause an increased duty to be obtained from the coals used in the manufactures; and the erection of a better class of engine, and also more efficient steam generators, will necessarily effect a saving in the fuel consumed to do a given amount of "work." The nation at large will, of course, be benefited by every such introduction of improved methods for producing its staple products at a less prime cost; but whether the proprietors of collieries—so far as such a process may be found to react upon their particular business and property—may be enabled to directly derive a corresponding benefit, is of course another matter, and may at times be open to question. But one thing, however, appears to be certain, and that is, that to meet the exigencies of the times in which we live every effort must be made to cheapen the production of this commodity also, so that the opportunity of insuring a reasonable return upon invested capital may not wholly disappear. Companies, or private proprietors, may go on losing money for a time, but it is in the very nature of things that a limit will sooner or later be reached, when production under such circumstances must necessarily cease. Production, to be healthy and stable, must be adequately remunerative to the immediate proprietors, for without this there will, as a rule, be no spirited development of the property, and not much disposition to forego a small immediate advantage for the purpose of securing a larger ultimate benefit.

A colliery property is of that nature that under ordinary circumstances the earliest years of its working are its best years, provided markets are reasonably favourable; and an old colliery with a long haulage, great length of airways to maintain, and long haulage levels to keep open, is necessarily loaded with an incubus which very considerably increases the cost of production; hence, according to all sound principles of safe investment, not only should a good interest on capital be obtainable in the earlier years of a colliery's working, but a steady recoupment of capital should also be attainable during the same period; and it is not saying too much to aver that the capital at first invested in a colliery should be recovered at

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such an annual rate and within such a period as, bearing a certain relation to the total expended fixed capital and the acreage under lease, would insure its complete recoupment while yet the age and circumstances of the property will bear the charge, without abstracting from the attainable profits any portion of the sum legitimately due as interest on both fixed and floating capital and proper trade profits. Colliery property in the course of production is necessarily undergoing a process of exhaustion, and the recoupment of the fixed capital expended upon the property should be distinctly provided for in the best period of the "trade life" of the concern; this is quite a different matter from that maintenance in good repair of all the vital parts of the plant, &c., which more distinctly and obviously forces itself upon the constant attention of the working department. And just as a person who gives £300 for a leasehold house and premises, yielding a clear annual rent of £21, and which has seven years unexpired, may perhaps imagine that he is investing his money at 7 per cent. per annum, and finds at the end of seven years his capital wholly gone; so, where the above principle of constant recoupment is not acted upon, will many find to their grief that after putting their money into some of the colliery properties offered to their notice from time to time, supposing they should indeed be so fortunate as to get a yearly interest paid for some few years upon their investment, and this perhaps done with difficulty, they have only to go "comfortably" on a few years more to find the property used up, and no probable chance of seeing their original investment ever return to them again.

In looking around and judging of the general appearances of this class of property, it may be supposed that a fixed capital of £100,000 is often thought to be too insignificant for the respectability of an ordinary colliery, turning out an average of 500 tons per day; and we sometimes see concerns which, though they may have a capacity to do more than is here indicated, yet, with the fluctuations of demand, really do not greatly exceed it, upon the average of the whole year, burdened with capitals of two or three times the above amount.

To recoup such capitals while yet the property has a chance

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of bearing the charge is itself, in the absence of unusual advantages, a huge burden ; and when this can be done, and something like 7 per cent. per annum paid on the fixed capital—a by no means extravagant proposition—and other legitimate charges provided for, the property may fairly be considered to be no ordinary acquisition. But if we may judge of the general practice from the reports which appear in the public papers from time to time, one may be led to think that the recoupment of the capital but seldom enters into the calculation of mining companies, and more seldom still is any distinct and systematic provision made for it.

Whether this annual amount should be immediately distributed to the shareholders or invested in securities to provide for a future operation, whether by annual drawings or by a reservation to a fixed period when it is a public company, the proprietors would have no difficulty in themselves deciding ; in the case of a private company the amount would, of course, be acquired immediately, and be available accordingly.

If a capitalist invests his money in securities of a sound description he receives his periodical profits, and his time and energies are at his own disposal ; and certainly when any man invests his money in a concern, and also employs his own energies in conducting it, he should not only be able to secure adequate interest on his capital as such, but should also be able to make proper trade profits commensurate with the risks naturally attending the class of business carried on.

Vast amounts are sunk in this class of property, and it needs no particularising to state that in a host of instances the original ordinary capital is sunk, virtually and absolutely beyond recovery. This result, so disastrous to the original shareholders, is brought about in different ways : sometimes by preposterously large sums of money being given for a concern which has not got the shadow of a chance of a remunerative existence in ordinary times, and only a fitful existence in a period of unnatural inflation of demand and consequent high prices ; and then no sooner does the fluctuation of trade bring around the certain period of succeeding depression, than a process of adverse results sets in, and the period that such a concern

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can keep afloat depends generally upon the length of time, or something less, required to produce sheer exhaustion; sometimes varied by some feature of such a case as the foregoing, too much may be paid for getting the coal, or the physical characteristics of the field of operations may be very adverse; but by some one or more of these reasons combined, the fact remains that investments in this class of property in numberless instances turn out disastrous to the shareholders, and the only people deriving a distinct benefit from its operations are those who, whatever may be their claims, legitimately considered, can never be such as should, in taking effect, swamp the owners of the property, and render it impossible that they should derive that pecuniary benefit upon their investment to which they are justly and rightly entitled.

But as indicating in some measure the process of such an operation as the recovery of capital upon some large properties, let us show what must be the charge per ton on the produce for the purpose of recoupment, and to insure its taking effect within a reasonable time.

Take the case of a colliery property with a capital of £150,000, and which, except at a great sacrifice as to selling price, does not raise more than an average of 150,000 tons per annum; and consider further that such a concern should fairly be expected to recoup its capital in 25 years—what is the charge per ton on such an output that this operation involves—allowing it to be invested yearly at 4 per cent. per annum? The amount of this charge per annum for the above capital is £3,601 16s., or equal to 5·76d. per ton of coal produced. If we add to this an amount for interest on capital equal to 7 per cent. per annum, this will be a further sum of £10,500; or, on such an indicated output, a charge per ton of 16·8d., or, together, 1s. 10½d. per ton.

Or take another case. There is a concern with a paid-up capital of £250,000, and whose whole annual output does not, on an average, exceed 240,000 tons; by allowing the same period for recoupment (viz. 25 years), and at the same rate per cent., the charge per ton would be 6d., or a total of £6,003; add to this such an amount as would give 7 per cent. per annum on the

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capital as interest, and we require a further sum of £17,500, or an amount per ton equal to 17½d.; and these two amounts together make £23,503, or a rate per ton equal to 1s. 11½d.

We will suppose yet another case. Let us take the case of a concern with an involved capital of £400,000, and that there is produced on an average a total of about 375,000 tons per annum; and let us assign a corresponding period for recoupment, and at a like rate of 4 per cent. per annum, this case would require a charge per ton on such a quantity equal to 6·15d., or a total annual amount of £9,604 16s.; add to this an amount sufficient to yield 7 per cent. per annum on the capital amount, which would be £28,000, and we have a concern that should yield a clear balance per ton for these purposes equal to 2s., or a total of £37,604 16s. per annum.

It is no part of my intention to indicate that the capital amounts, in the foregoing cases, are such as should properly be sunk or expended in undertakings capable of yielding the output assigned to the several cases. Fixed or nominal capital, or actually expended capital, varies immensely in different concerns of nearly similar capacity. Its amount in any particular concern may be determined by fancy, or by purchasing at an (for the shareholders) unlucky time; or by abnormal difficulties in the development of the works; or by an unjustifiably extravagant expenditure, or some other circumstances which the shareholders either cannot or do not control. But if large nominal and called-up capitals add to the respectability of this class of trading concerns, there is no doubt this respectability is very generally attained. But no person who rightly estimates the risks and contingencies to which such property is liable will say that such a provision for recoupment and for interest as that before remarked upon should not be rigidly kept in view and provided for, if such investments are to rank anything higher than the most ordinary lotteries of some of the needy foreign governments.

It is also greatly to the interest of proprietors in the case of opening out and developing a new concern that the work should be carried through as expeditiously as possible, because the expenditure being generally great, the capital amounts

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expended in the several years taken to bring the concern into a paying or a productive condition would naturally be considerably increased if charged—as of course they legitimately may be—with a reasonable compound interest during the interim.

Let us suppose the case of such a concern costing in the aggregate, on capital account, £90,000, and that this expenditure was distributed over five years in somewhat of the following order:—

1st year's expenditure, say	..	..	£20,000
2nd do. do.	..	..	35,000
3rd do. do.	..	..	15,000
4th do. do.	..	..	15,000
5th do. do.	..	..	5,000
Total	..	..	£90,000

Then let us charge the expenditure of each year with compound interest, at the rate of 6 per cent. per annum:—

Four years' interest on 1st year's expenditure at 6 per cent. compound interest is	£5,249·53
Three years' interest on 2nd year's expenditure (£35,000) at same rate	6,685·56
Two years' interest on 3rd year's expenditure (£15,000) at same rate	1,854·00
One year's interest on 4th year's expenditure (£15,000) at same rate	900·00
Total accrued interest ..	£14,689·09
Capital expended	90,000
Total	£104,689·09

Which, therefore, gives the total capital in this case chargeable with interest and with recoupment when the concern commences to raise coal for the market. If we treat this case somewhat differently from the other cases worked out before, and charge it with an interest on capital at the rate of 6 per cent. per annum, and the recoupment at the same rate, and to

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be made up in a term of 20 years, we shall find that an annual charge of £9,127 6s. is required; and of this, £6,281 6s. 11d. will be for interest on capital, and £2,845 19s. 1d. will be the annual charge for the recovery of capital in 20 years.

Considering irregular trade and hindrances that may occur, an average output of 400 tons per day is as much as may be safely reckoned upon for the purpose of this computation; and counting this for 300 days, we have a total of 120,000 tons, which are to make up the foregoing charge. The recoupment would, therefore, involve a charge of 5·7d. per ton, and the interest at 6 per cent. would be 12·6d. per ton, or a total of 1s. 6¼d. in both amounts.

If it may be thought that the recoupment could not be invested annually at so high a rate as 6 per cent. per annum, we may compute it at 4½ per cent., and by doing so we find that it would require a yearly sum equal to £3,337 2s. for this purpose, or a charge per ton of 6·67d.

Thus it may be seen, from the foregoing series of cases, that with the selling price of coals of the best description at so low a figure as they now rule in times of depression, or even in ordinary times according to present prospects, it must be manifest that, even in the best situated concerns, it is no easy matter to produce coal at such a price as shall insure such a balance upon the sale of it as shall duly meet these and the other legitimate charges upon the property, and to provide against the peculiar risks and contingencies to which such a business is liable.

The operation of determining the value of a colliery to a person coming into possession as a purchaser—wishing to acquire it as a reasonably safe investment—is a process that requires very considerable thought and judgment, as well as much technical knowledge. Of course collieries, as well as other classes of property, may be bought and sold very much on the haphazard principle of roughly guessing the value, or the amount that may be paid for them; and this may also be done on a chance occasion without the chiefly interested parties, or the purchaser, suffering an absolute loss; it may also occur, through what may be, and generally is, termed a

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stroke of good luck, that a large sum of money may be made by a haphazard purchase ; while occasionally, on ever so carefully prepared a valuation of a mineral property, the purchase effected upon such a basis may not invariably give satisfactory results ; and this may arise either from some unforeseen difficulty being met with in the course of the development of the concern, or from unfavourable fluctuations of the market prices for the produce, or some other trade difficulty; or the exclusion of some material fact which it was important to take into consideration in order to arrive at a just value, and which may have been purposely withheld or overlooked, may have an adverse influence upon the continued prosperity of the property ; but neither of these results can prove the unwisdom of procuring the most reliable technical and practical valuation of a concern that can be secured when a purchase of this class of property is in contemplation. If this was more generally done by competent persons there would not be so many disappointments in this class of investment.

The market value of any particular property is also largely varied by the conditions of labour available for its working. Some districts are notoriously worse than others in this respect ; and these peculiarities may occasionally make the whole difference between a concern that pays moderately, and one working at a loss. Old-established abuses develop in time into crystallized forms, and become the idiosyncrasies of a district ; and these in their operation frequently drag down concerns to the dirt which would otherwise be flourishing, or at least be able to exist respectably.

CHAPTER V.

NOTES ON RATING.

THE amount at which any particular colliery should be rated under the statute 43 Elizabeth, c. 2, s. 1, is a quantity that ought, no doubt, to bear some relation to the *profit-yielding*

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capacity of the concern. But to assess any given property on profits solely, would be not only contrary to the plain language of the statute in that respect, but would also be as unjust to the proprietor as it would be to regulate the wages to be paid for labour at that concern in proportion to the profits actually made; and the natural effect of the latter operation would be to virtually deprive the proprietors of the just fruits of their superior skill and commercial ability in the conduct of the management, where such were exercised, and reduce their result to the level of those who exercise neither; nay, it would practically place the former at a disadvantage, in comparison with those whose operations issue in nothing but loss.

The true basis for estimating the rating value of a property has been defined by the Court of Queen's Bench to be "the actual value of the property to the owner, whether it remains in his own occupation or is let to a tenant."

But it would further appear that the royalty reserved by the lease has not, as a rule, been accepted by that court as a proper maximum rent in ordinary cases, but, on the contrary, there seems to be a considerable concurrence in the decisions given in contested cases, that that payment is to be looked upon as a possible minimum, below which the sum total for assessment purposes should not, as a rule, go; but it is difficult to see why the royalty reserved should not sometimes be subject to an abatement, if it is to be subject in certain cases to an increase.

A principle appears to have been established and acted upon by the court, that, at the period of making the rate, the lessor or owner of the freehold is to be assumed to have entire possession of the property and of everything in the way of "fixtures" in and upon the colliery, which contribute for the time being to its value for letting purposes, and for the economical production of the rateable commodity; and that the "hypothetical" tenant is to be assumed to enter into possession, with the tenancy in this condition, and to pay a reasonable rent accordingly for the concern in full working order.

The natural inference to be drawn from this established

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principle is, that the royalty per ton reserved by the lease, if it is a reasonable royalty for the time being and under the circumstances then found to be existing, should be taken as the basis for fixing the rateable value; and if it is not, then an adjusted royalty to meet the present time and circumstances, increased by a certain percentage of interest on the capital value of all the erections, fixed plant, and machinery, as well as of any other permanent or subsidiary plant or machinery which may then be in use, and contributing thereby to the economical working and delivery of the produce, from the point of its severance from the estate to the point of its delivery over the screens or tips at the colliery bank, at which point it ceases to be subject to consideration for rating purposes; and this, added to a rent for occupied and damaged land, is the *maximum amount* to be taken, and from which certain deductions are to be made, in order to arrive at the net rateable value. The next point then to consider is what deductions from this maximum should be made, sanctioned by the statute, so as to arrive at the net rateable value.

It was formerly contended with great persistency by those taking a leading part in the valuation of colliery property that an annual deduction from the rateable value should be made, in consideration that the working of the coal was an exhaustion of the *corpus* of the estate; but inasmuch as the colliery would cease to be rateable at all so soon as that *corpus* became actually exhausted, we could never (after studying the matter closely) see the propriety of such a deduction. If the estate was perpetually rateable, at some fixed price per acre or in some other way, in consideration of the minerals it contained or may have contained, then, doubtless, the royalty as it became payable upon the severed coal should be capitalised, and the rate charged upon some determinate proportion of the annual interest in perpetuity that the capitalised rent would produce, and on some such principle (so far as it could be made applicable) as the surface of the estate is rated. But such is not the case, for when the colliery is exhausted, and that portion of the *corpus* of the estate gone, it is no longer on that account rateable. We believe that by some of its former

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advocates this contention has now been abandoned; and the Judges of the Court of Queen's Bench seem always to have ruled against it.

But while the previous contention does not appear to be legitimate, there is the matter of a deduction for the *redemption* of the *capital* value of the erections, plant, machinery, shaft, &c., within a proper period, which ought certainly to be made; because much of the expenditure represented by these erections, if not the great bulk of it, will cease to be of any value to the owner, otherwise than as constituting a part of the property upon which it has been expended, and upon which the rate is levied; and every such commercial undertaking of a sound and profitable nature should have returned or recouped its expended capital, as well as yielded proper interest, against that period when the lease would expire or the property became exhausted of its demised minerals. Taking, therefore, the value of all the fixed capital at the time of making the rate, a sum of money which shall for that year be deemed a proper amount for the proportionate redemption of that capital within a certain calculated period will form a legitimate and proper deduction. There are other deductions that it would be also proper to make in order to place the rating of collieries on a level with other classes of property, which are surrounded by incomparably less risks to losses and disasters. But the method adopted in different districts may differ; and a comparative scale may be worked upon for the veins of a particular district, in which all the surrounding circumstances may be taken into consideration, both as regards those general conditions of accessibility and quality, and the facilities for production, and also of the deductions proper to be made in such cases; and the rate then levied equitably on the ton of coal produced under these comparative conditions. Where this can be done it simplifies the matter very much, and should be conducive to amicable working. It is well known that the several veins of coal differ considerably both in their intrinsic value for economic purposes when actually arrived at, and also in the different charges which their extraction involves; they differ also in the quantity that can be extracted

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from a given area of ground to every foot of thickness of the vein, and consequently in those charges that are either increased or diminished very much in proportion to the quantity of coal that can be extracted from that area; and the actually procurable quantity differs again in the proportion of marketable large coal that is ultimately available to the owner for sale purposes.

Nothing therefore but a careful and competent review of all the features of this important subject can insure its being treated with fairness to all parties, and without improperly increasing the natural burdens under which this class of property is developed, and its consequent trade carried on.

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